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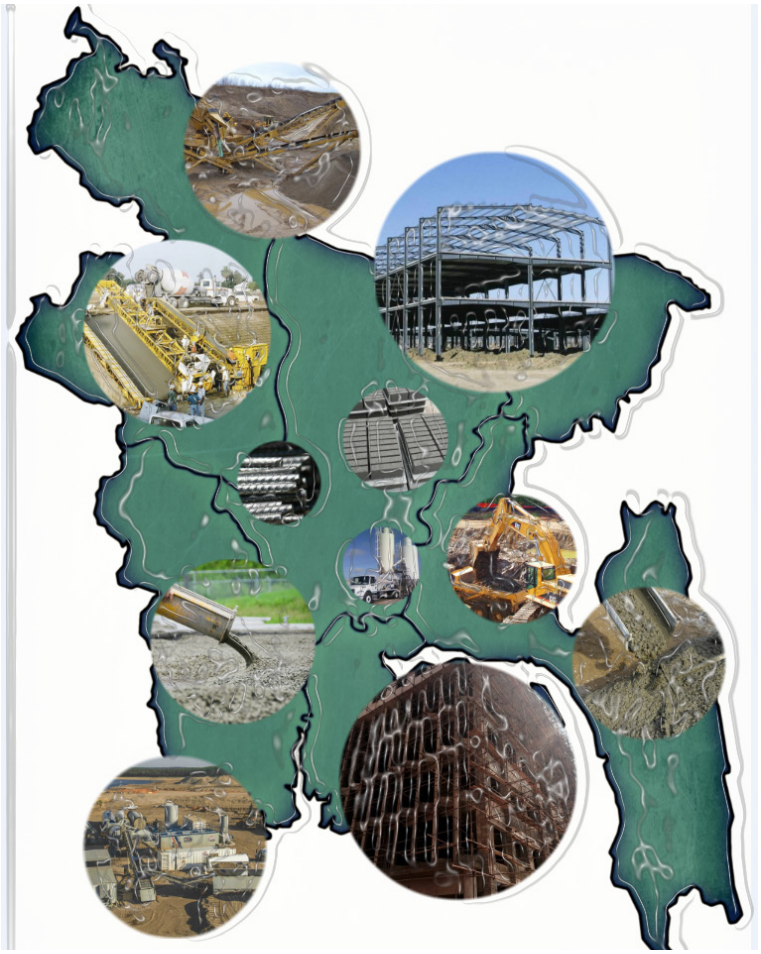
FY16 T45 Contingency Base Site Evaluations for Tactical Environment

Construction Material-Based Methodology for Military Contingency Base Construction

Case Study of Dhaka, Bangladesh

Ghassan K. Al-Chaar, George W. Calfas, Michael A. Weiss,
Michael K. Valentino, and Patrick J. Guertin

August 2016



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Abstract

To sustain itself as the world's premier land power, the Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited Contingency Bases (CBs) allow the Army's expeditionary forces to rapidly respond and attack the enemy throughout the joint area of operations (JOA). Strategic conditions will be analyzed through the lens of eight OE variables—political, military, economic, social, information, infrastructure, physical environment, and time (PMESII-PT). The Army has neither a well-grounded methodology nor the tools that enable this strategic decision-making capability. Decision makers require reliable information about the situational dynamics of the operational environment to anticipate the impacts that siting and operating CBs will have on the local context, and to consider the effects of the sites on the operation of CBs. This capability to anticipate CB impacts and resources draws upon knowledge gleaned from the local population and becomes particularly important for engagement operations when CBs will have a longer duration of use and interaction with the local populace. This report considers access of building materials required for the construction of CBs and develops a methodology for strategically siting CBs that can be replicated in other locations throughout the world. This work then validates the developed methodology with a case study of Dhaka, Bangladesh.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
hectares	1.0 E+04	square meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Abbreviations

Term	Meaning
ACC	acid-copper-chrome
AKS	Abdul Khair Steel Ltd.
ASTM	American Society for Testing and Materials
BBMOA	Bangladesh Brick Manufacturing Owners Association
BDS	Bangladesh Standards
BFD	Bangladesh Forest Department
BFIDC	Bangladesh Forest Industries Development Corporation
BFRI	Bangladesh Forest Research Institute
BIS	Bureau of Indian Standards
BNBC	Bangladesh National Building Code
BS	British Standards
BSRM	Bangladesh Steel Re-Rolling Mills
BSTI	Bangladesh Standards and Testing Institute
BWP	boiling water proof
BWR	boiling water resistant
CAGR	calculated average growth rate
CB	Contingency Bases
CB-SITE	Contingency Base Site Identification for the Tactical Environment
CCA	copper-chrome-arsenate
CCB	copper-chrome-boric acid
CHT	Chittagong Hills Tract
DDT	dichlorodiphenyltrichloroethane
DRI	direct-reduced iron
EAF	electric arc furnace
EIA	environmental impact assessment
EN	European Norms
ESM	European Standard Methods
FCBTK	Fixed Chimney Bull's Trench Kiln
FEMA	Federal Emergency Management Agency
FOB	Forward Operating Base
GIS	geographical information system
GNP	gross national product
IUCN	International Union for Conservation of Nature
JOA	Joint Area of Operations

Term	Meaning
KSRM	Kabir Steel Re-Rolling Mills
LGED	Local Government Engineering Department
MDF	medium-density fiberboard
MR	moisture resistant
MT	Metric ton
MTPA	metric ton per annum
NATIP	National Timber Industry Policy
OPC	ordinary Portland cement
PCC	Portland composite cement
PDF	population density factor
PMESII-PT	political, military, economic, social, information, infrastructure, physical environment, and time
SAIL	Steel Authority of India, Ltd.
SBRI	shipbreaking and recycling industry
SCM	supplementary siliceous materials
TMT	thermo-mechanically treated
URM	unreinforced masonry
USDA	U.S. Department of Agriculture
USGS	U.S. Geographical Survey
UTM	ultrasonic thickness machine
VSBK	vertical shaft brick kiln

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Preface

This study was conducted for the Department of the Army under applied research program T45, Project 45509, "Contingency Base Site Evaluations for Tactical Environment." The technical monitor was Mr. Kurt Kinnevan, CEERD-CZT.

The work was performed by the Environmental Processes Branch (CNE) of the Installations Division (CN), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Mr. Garth Anderson was Chief, CEERD-CNE; Ms. Michelle Hanson was Chief, CEERD-CN; and Mr. Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. Jeffery P. Holland.

1 Introduction

1.1 Background

To sustain itself as the world's premier land power, the U.S. Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically-sited Contingency Bases (CBs) allow the Army's expeditionary forces to rapidly respond and attack the enemy throughout the joint area of operations (JOA). The Army has neither a well-grounded methodology nor the tools that enable this strategic decision-making capability. Decision makers require reliable information about the situational dynamics of the operational environment to anticipate the impacts that siting and operating CBs will have on the local context, and to consider the effects of the site on the operation of CBs. This capability to anticipate CB impacts on a local context becomes particularly important for engagement operations where CBs will have a longer duration of use and interaction with the local populace. Understanding these potential impacts enables decision makers to evaluate implications of the effects of the CB life cycle for commander's intent in the pre-operational planning stage.

This project develops a contingency site selection process that does not currently exist for mission planners. The more efficient siting of CBs will assist in the reduction of materiel demand, minimize footprint, reduce risk to Soldiers, and preserve freedom of maneuver and action. Contingency Base Site Identification for the Tactical Environment (CB-SITE) will enable expeditionary planning to occur prior to deployment. A geospatial decision-support tool that integrates the operational environment into considerations for CB design can also be used to train future planners, designers, builders, operators, and managers of CBs. Given a capability to display real-time effects that flow from parametric changes, instructors would have the means to prepare students for both expected and unexpected operational situations once deployed. This resource would also provide CB operators and managers with a tool to assist in the analysis of their camps' operational effectiveness as well as to test potential operational/design outcomes based on available local resources and sociocultural impacts, prior to initiating them in practice.

Construction of military facilities is one of the most important aspects of military missions. Lessons learned from past deployments show that the construction of Forward Operating Bases (FOBs) within the boundaries of host nations can be costly in terms of money, time, and effort. As a result, this current effort is designed to look at the availability of locally-sourced materials and their suitability for supporting the military mission. Future considerations of military site selection for the Army is on unconventional warfare and assistance in areas of world that are densely populated. As such, the region around Dhaka, Bangladesh, which is one of the most densely populated areas in the world, is used as a case study to develop this methodology.

Research was conducted for the city of Dhaka, which is the capitol of country of Bangladesh and is located in the Dhaka division and district. The country of Bangladesh and city of Dhaka are shown in Figure 1 and Figure 2. Bangladesh is located between 20.34° and 26.38° N latitude and between 88.01° and 92.41° E longitude. Bangladesh is bordered by the Indian states of West Bengal in the north and west, Assam in the north, Meghalaya in the north and northeast, and Tripura and Mizoram in the east. The southeast shares a border with Myanmar (Burma). In the south of Bangladesh is the Bay of Bengal. The country of Bangladesh is a total area of 56,977 square miles, and the capital is Dhaka. The country is divided into eight major divisions: Khulna and Barisal in the southwest, Rajshahi and Rangpur in the northwest, Mymensingh and Sylhet in the northeast, Chittagong in the southeast, and Dhaka in the center.

Figure 1. Location of the city of Dhaka within the country of Bangladesh (Google Maps, 2016).

Figure 2. The city of Dhaka, Bangladesh (Google Maps, 2016).

Bangladesh can be divided into three major regions: hills, terraces, and floodplains. Floodplains represent 80% of the country, and they are

formed by three major rivers together with their tributaries and distributaries. Hilly areas represent 12% of the country and are located in the north and south, while terrace areas represent 8%.

The three major rivers in Bangladesh are the Ganges, Brahmaputra, and Meghna. The Ganges and Brahmaputra enter through the west and north border with India into Bangladesh, combine west of Dhaka, and exit into the Meghna River south of Dhaka; the Meghna river starts in the northeast and exits into the Bay of Bengal in the south. The river network of the country is very dense, with more than 250 rivers crisscrossing Bangladesh. These rivers support agriculture, navigation, groundwater recharge, fish habitats, and land-building activities since ancient times.

Bangladesh has a humid subtropical climate with wide seasonal variations in rainfall that bring warm temperatures and high humidity. The three distinct seasons are summer (March–May), the monsoon season (June–October), and the winter or dry season (November–February). Due to the effects of monsoon, high-intensity rain-bearing winds produce an annual rainfall exceeding 60 inches, which leads to a heavy river flooding between June and October yearly. The winter season is cool and dry with little rainfall, while the summer is the hottest part of the year (Corner 2014).

Bangladesh has a population of 156.8 million (2014 estimate), and the official language is Bengali. The economy of Bangladesh mostly consists of an agrarian workforce, with 48% of labor force engaged in agriculture-related activities. There are concerns about pressure on the country's natural resources due to the ever-growing population in Bangladesh. Also with population growth, the percentage of people living in urban areas has been rising, with 33.5 million (2011 estimate) of the Bangladesh population living in cities (Corner 2014).

1.2 Objective

This effort falls under the CB-SITE program. CB-SITE's goal is to develop a geographical information system (GIS)-based decision support tool to assist Army Headquarters-level staffs in siting FOBs in theater.

This effort addresses the availability of appropriate construction materials within the host nation including local material standards, quantities, and accessibility. The work's objectives were set in order to address the following considerations:

- Development of country-specific construction materials databases.
- Development of a methodology that defines accessibility of construction resources based on FOB location, transportation network, population densities, and centers of materials.

1.3 Methodology

Site-selection methodologies are expected to merge into unified methodology at which all relevant factors are addressed, analyzed, and optimized to yield the best solution for decision making on where best to select a site for military missions.

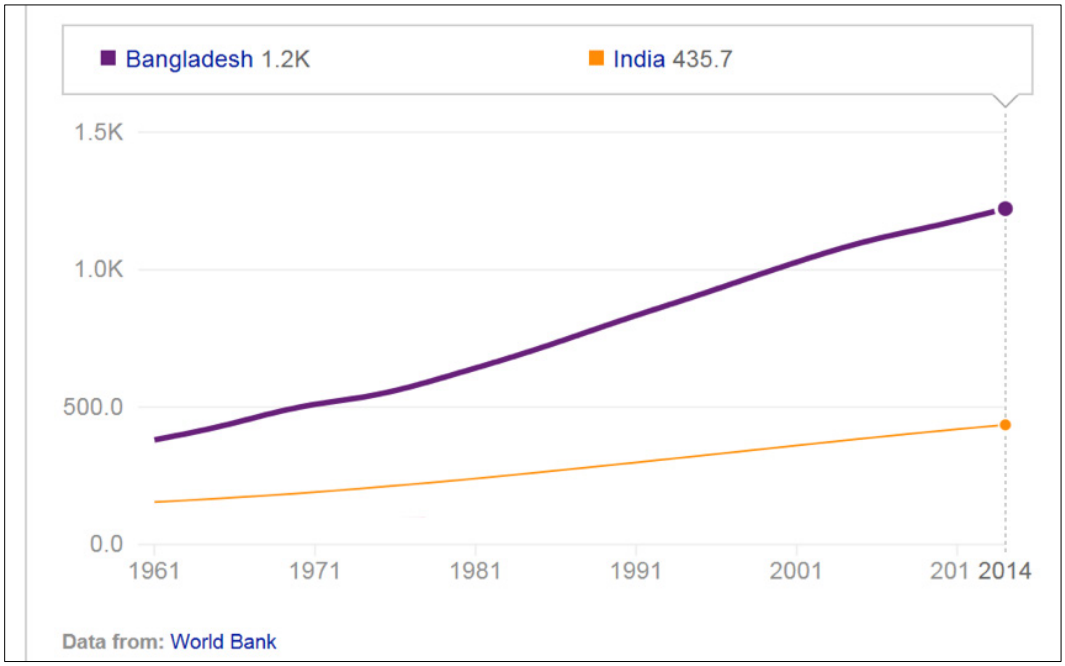
Availability of construction materials near the site is one of many criteria that would impact military missions. As the title implies, this report is a limited study on "Construction Material-Based Methodology for Military Site Selection."

Because every location in a particular region is unique in many aspects, a single general methodology would not work well, because it would not capture all variables specific to the region under consideration. In rare cases, methodologies can be similar and can be modified to suit other similar areas. However, it is critical in any case to identify the relevant set of variables that must be reflected in the adopted methodology.

In the planning stage of any mission, a preparation study is required to finalize a methodology suitable for the mission. For this report's effort, a hypothetical case study was chosen for the city of Dhaka in Bangladesh. Dhaka is a megacity in a densely populated country.

Certainly, site selection in such an area with a high density of the population is influenced by that density of population, among other features. Figure 3 shows that the recent population density of Bangladesh is about 2.75 times that of India. The population density of Dhaka is about 50,001 people per square mile. Therefore, any site selection methodologies should include a population density factor (PDF). Other relevant factors will be addressed in subsequent sections of this chapter.

Figure 3. Population density for Bangladesh and India ("Population Density" 2016).



1.3.1 General regions

Table 1 provides the population and densities for the eight divisions in Bangladesh, along with the largest neighboring city from a nearby country (Agartala, India). These locations are depicted in

Figure 4. The populations by division, along with respective cities of 100,000 or more people, can be found in Table A1 in the appendix of this report.

Table 1. Population and densities major divisions (Population and Housing Census-2011 [2014]).

Region	Population	Density (people per sq. km)
Barisal Division	8,325,666	626.1
Chittagong Division	28,423,019	841.6
Dhaka Division	36,054,418	1,772.8
Khulna Division	15,687,759	704.4
Mymensingh Division	11,370,000	1,039.9
Rajshahi Division	18,484,858	1,015.8
Rangpur Division	15,787,758	967.6

Region	Population	Density (people per sq. km)
Sylhet Division	9,910,219	12,596
Agartala, India	522,613	6,831

Figure 4. Major regions in and around Bangladesh ("Bangladesh" 2011).

For site selection in or near the vicinity of Dhaka, the first requirement is to determine the boundaries so that the effective area can be isolated with minimum effects from adjacent areas. It is recommended here to consider the following effective areas, for simplicity and accuracy of this analysis:

- City effective region (Dhaka)
- Country effective region (Bangladesh)
- Cross-country effective region (Bangladesh and adjacent part of India)
- Cross-countries effective regions (Bangladesh and nonadjacent countries with heavy trades)

Each region has a special level of interaction that affects the flow of construction materials to be distributed to a site under consideration. The aforementioned definitions of effective areas will help in determining a methodology for a particular region.

Using the main regions from

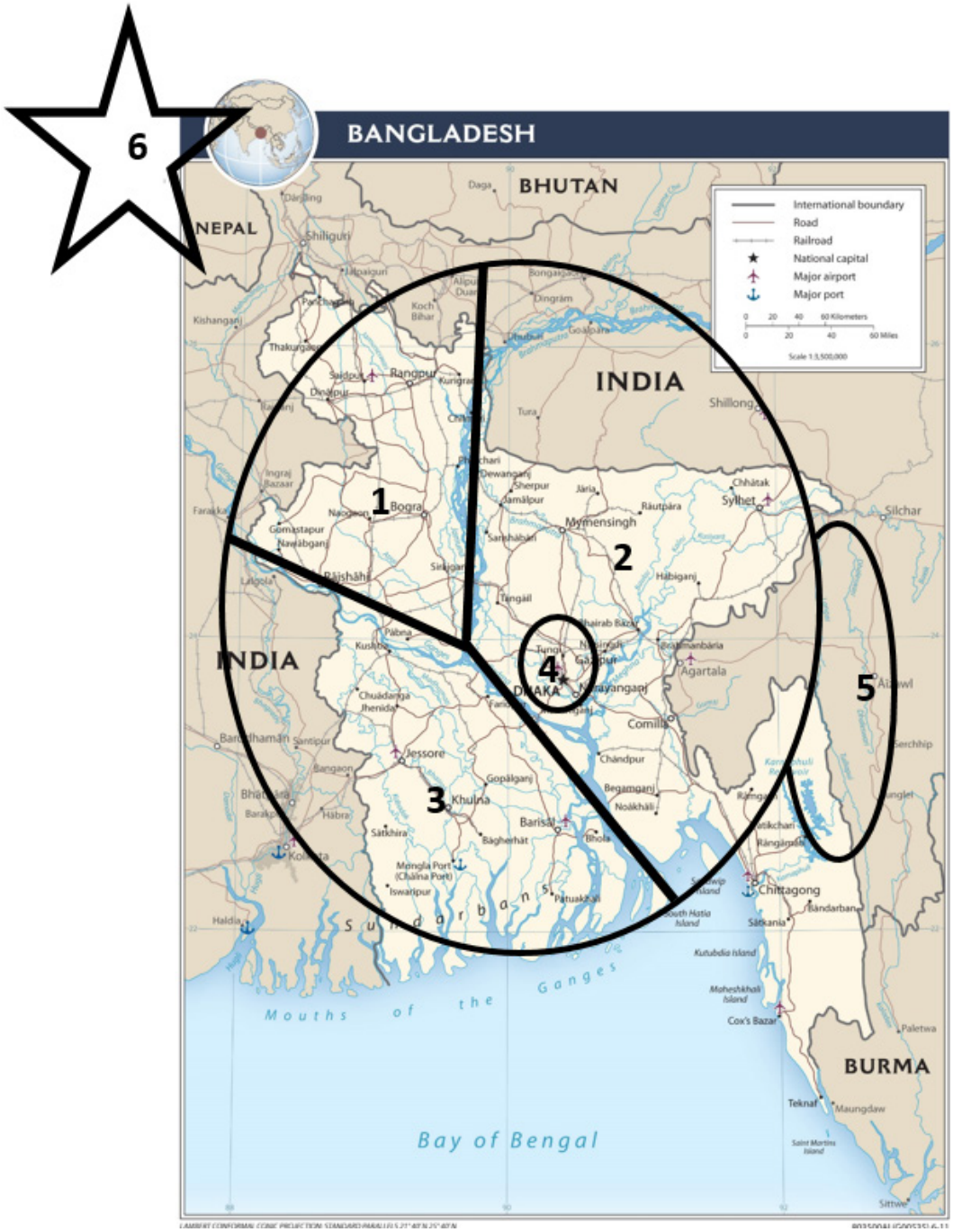
Figure 4, in conjunction with the descriptions provided above, the country of Bangladesh can be further subdivided into three main regions by using the rivers within the country. Figure 5 provides the regions considered for the analysis of the Dhaka case study.

The rivers were used to divide the country into sections, because water barriers limit much of the trade and business actions within the country. For purposes of this construction material case study, there are three other regions considered. The first is the main city under consideration, which in this case is Dhaka. The next region is an adjacent country's largest nearby city, which is Agartala, India for this case study. Lastly, the final region to be considered is a nonadjacent country that is a heavy trade partner with the country or city under consideration for base selection. For the purposes of this case study, it was determined that there was no heavy trade partner.

Hence, the regions analyzed for this case study are classified as:

- *Region 1*: northwest Bangladesh
- *Region 2*: southwest Bangladesh
- *Region 3*: northeast and southeast Bangladesh
- *Region 4*: Dhaka, Bangladesh
- *Region 5*: neighboring country's largest nearby city – Agartala, India
- *Region 6*: heavy trade partner with nonadjacent region (not applicable for this case study)

Figure 5. Major regions for analysis ("Bangladesh Transportation" 2011).



1.3.2 Building types

The Federal Emergency Management Agency (FEMA) classifies 15 different main types of buildings. These building types must be examined in order to properly evaluate a region's construction material needs and feasibility based on structure type. The various building types and their respective key properties are described below.

1.3.2.1 Building Type 1: wood light frames

W1 – These buildings are single or multiple family dwellings of one or more stories with light building loads. The first floor may be slab-on-grade or wood raised above grade with cripple stud walls and post-and-beam supports. Floor and roof framing consists of short, closely spaced wood joists or rafters supported on wood studs. Lateral support is provided with shear walls of plywood, stucco, gypsum board, and a variety of other materials (FEMA 310 1998).

W1A – These buildings are multistory, multi-unit residences that are framed with the same systems as W1, but they are often built on top of open front garages. The first story consists of wood floor framing on wood stud walls and steel pipe columns, or a concrete slab on concrete or concrete masonry block walls (FEMA 310 1998).

1.3.2.2 Building Type 2: wood frames, commercial and industrial

W2 – These buildings are commercial or industrial buildings with a floor area of 5,000 square feet or more and are constructed primarily on wood framing. The floor and roof framing consists of wood joists and wood or steel trusses, glulam or steel beams, and wood posts or columns. Lateral forces are resisted by wood diaphragms and exterior stud walls sheathed with plywood, stucco, or wood sheathing, or sometimes rod bracing or a spot steel-braced frame. Large wall openings are common for storefronts or garage openings (FEMA 310 1998).

1.3.2.3 Building Type 3: steel moment frame

S1 – These buildings consist of an essentially complete frame assembly of steel beams and columns. Lateral forces are resisted by moment frames that develop stiffness through rigid connections of the beam and columns created by angles, plates, and bolts, or by welding. Moment frames may be developed on all framing lines or only in selected bays. It is significant that no structural walls are required. Floors are cast-in-place concrete slab or metal deck and concrete. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural column furring. Foundations consist of concrete spread footings or deep pile foundations (FEMA 310 1998).

S1A – These buildings are similar to S1 buildings, except the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck that are flexible relative to the frames (FEMA 310 1998).

1.3.2.4 Building Type 4: steel-braced frame

S2 – These buildings consist of a frame assembly of steel columns and beams. Lateral forces are resisted by diagonal steel members placed in selected bays. Floor and roof framing consist of cast-in-place concrete slabs or metal deck on concrete. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural furring. Foundations consist of concrete spread footings or deep pile foundations (FEMA 310 1998).

S2A – These buildings are similar to S2 buildings, except the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck (FEMA 310 1998).

1.3.2.5 Building Type 5: steel light frame

S3 – These buildings are pre-engineered and partially prefabricated with transverse rigid steel frames. They are one-story in height. The roof and walls consist of lightweight metal, fiberglass, or cementitious panels. Rigid frames in the transverse direction and light rod diagonal bracing in the longitudinal direction resist lateral forces. Diaphragm forces are resisted by untopped metal deck, roof panel shear elements, or a system of tension-only rod bracing (FEMA 310 1998).

1.3.2.6 Building Type 6: steel frames with concrete shear walls

S4 – These buildings consist of a frame assembly of steel beams and steel columns. The floors and roof consist of cast-in-place concrete slabs or metal deck with or without concrete fill. The buildings feature a significant number of concrete walls effectively acting as shear walls, either as vertical transportation cores isolated in selected bays, or as a perimeter wall system. The steel column-and-beam system may act only to carry gravity loads or may have rigid connections to act as a moment frame. The buildings will generally be mid- or low-rise (FEMA 310 1998).

1.3.2.7 Building Type 7: steel frames with infill masonry shear walls

S5 – This is an older type of building that consists of a frame assembly of steel beams and steel columns. The floor consists of masonry flat arches, concrete slabs or metal deck, and concrete fill. Exterior walls and possibly some interior walls, are constructed of unreinforced solid clay brick, concrete block, or hollow-clay tile masonry infilling the space between columns and beams. Windows and doors may be present in the infill walls but to act effectively as shear-resisting elements, the infill masonry must be constructed against the columns and beams (FEMA 310 1998).

S5A – These buildings are similar to S5 buildings, except the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck (FEMA 310 1998).

1.3.2.8 Building Type 8: concrete moment frames

C1 – These buildings consist of concrete framing, either a complete system of beams and columns or columns supporting slab without gravity beams. Lateral forces are resisted by moment frames that develop stiffness through rigid, monolithic beam-column connections. Moment frames may be developed on all framing lines or only in selected bays. It is significant that no structural walls are required. Floors are cast-in-place or precast concrete. Foundations consist of concrete spread footings or deep pile foundations (FEMA 310 1998).

1.3.2.9 Building Type 9: concrete shear wall buildings

C2 – These buildings have floor and roof framing that consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Lateral forces are resisted by cast-in-place concrete shear walls. Floors are supported on concrete columns or bearing walls. The diaphragms consist of concrete slabs and are stiff relative to the walls. Foundations consist of concrete spread footings or deep pile foundations (FEMA 310 1998).

C2A – These buildings are similar to C2 buildings, except the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck, and they have large aspect ratios (FEMA 310 1998).

1.3.2.10 Building Type 10: concrete frames with infill masonry shear walls

C3 – These buildings consist of concrete framing, either a complete system of beams and columns or columns supporting slabs without gravity beams. Exterior walls and possibly some interior walls are constructed of unreinforced solid clay brick, concrete block, or hollow-clay tile masonry infilling the space between columns and beams. Windows and doors may be present in the infill walls but to act effectively as shear-resisting elements, the infill masonry must be built against the columns and beams (FEMA 310 1998).

C3A – These buildings are similar to C3 buildings, except the floors and roof that act as flexible diaphragms, such as wood or untopped metal deck, and they have large aspect ratios (FEMA 310 1998).

1.3.2.11 Building Type 11: precast/tilt-up concrete shear wall buildings

PC1 – These buildings are one or more stories in height. They are constructed with perimeter concrete walls precast on the site and tilted up from the exterior of the buildings, to support all or a portion of the perimeter roof load, and they provide seismic shear resistance. Floor and roof framing consists of wood joists, glulam beams, steel beams, or open web joists. Framing is supported on interior steel columns and perimeter concrete bearing walls. Foundations consist of concrete spread footings or deep pile foundations (FEMA 310 1998).

PC1A – These buildings are similar to PC1 buildings, except that diaphragms consist of precast elements, cast-in-place concrete, or metal deck with concrete fill, and they are stiff relative to the walls (FEMA 310 1998).

1.3.2.12 Building Type 12: precast concrete frames

PC2 – These buildings consist of concrete columns, girders, beams, and/or slabs that are precast off the site and erected to form a complete gravity-load system. Lateral forces are resisted by precast or cast-in-place concrete shear walls. Floor and roof framing consist of precast concrete planks, tees, or double-tees supported on precast concrete girders and columns. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs (FEMA 310 1998).

PC2A – These buildings are similar to PC2 buildings, but obtain lateral support from specially connected precast girders and columns that form moment frames. These connections are either welded inserts or cast-in-place concrete closures. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs. This type of construction is not permitted in regions of high seismicity for new construction (FEMA 310 1998).

1.3.2.13 Building Type 13: reinforced masonry bearing wall buildings with flexible diaphragms

RM1 – These buildings have bearing walls that consist of reinforced brick or concrete-block masonry. Wood floor and roof framing consists of wood joists, glulam beams, and wood posts or small steel columns, whereas steel floor and roof framing consists of steel beams or open web joists, steel girders, and steel columns. Lateral forces are resisted by the reinforced brick or concrete block masonry shear walls. Diaphragms consist of straight or diagonal wood sheathing, plywood, or untopped metal deck, and they are flexible relative to the walls. Foundations consist of brick or concrete spread footings (FEMA 310 1998).

1.3.2.14 Building Type 14: reinforced masonry bearing wall buildings with stiff diaphragms

RM2 – These buildings are similar to RM1 buildings, except the diaphragms consist of metal deck with concrete fill, precast concrete planks, tees, or double-tees, with or without a cast-in-place concrete topping slab, and are stiff relative to the walls. The floor and roof framing is supported on interior steel or concrete frames or interior reinforced masonry walls (FEMA 310 1998).

1.3.2.15 Building Type 15: unreinforced masonry bearing wall buildings

URM – These buildings consist of unreinforced masonry (URM) bearing walls, usually at the perimeter and usually brick masonry. The floors are wood joists and wood sheathing supported on the walls and on interior post-and-beam construction or wood-stud bearing walls. Interior bearing walls, when present, also consist of unreinforced clay brick masonry. The diaphragms are flexible relative to the walls, and when they exist, ties between the walls and diaphragms consist of bent steel plates or government

anchors embedded in the mortar joints and attached to framing. Foundations consist of brick or concrete spread footings (FEMA 310 1998).

URM-A – These buildings are similar to URM buildings, but features all floors and/or roof constructed of materials that form a rigid diaphragm, usually concrete slabs or steel joists with flat-arched unreinforced masonry. In regions of low seismicity, more recent construction consists of metal deck and concrete fill supported on steel framing (FEMA 310 1998).

Overall, the 15 different buildings types have different construction methods and materials, both of which must be taken into account when determined the most suitable building type for a particular region (FEMA 310 1998).

As stated previously, the importance of these building types must be examined in order to properly evaluate a region's construction material needs and feasibility based on structure type. Table 2 provides a ranking of a building type's importance in terms of most and least suitable for the region. It was determined that due to availability of construction resources as well as conditions within the country, reinforced masonry walls – flexible (Building Type 13), wood light frames (Building Type 1), and unreinforced masonry walls (Building Type 15) are the most suitable FEMA building types for the Dhaka region.

Table 2. Ranking of FEMA building types, from most to least suitable (ERDC-CERL).

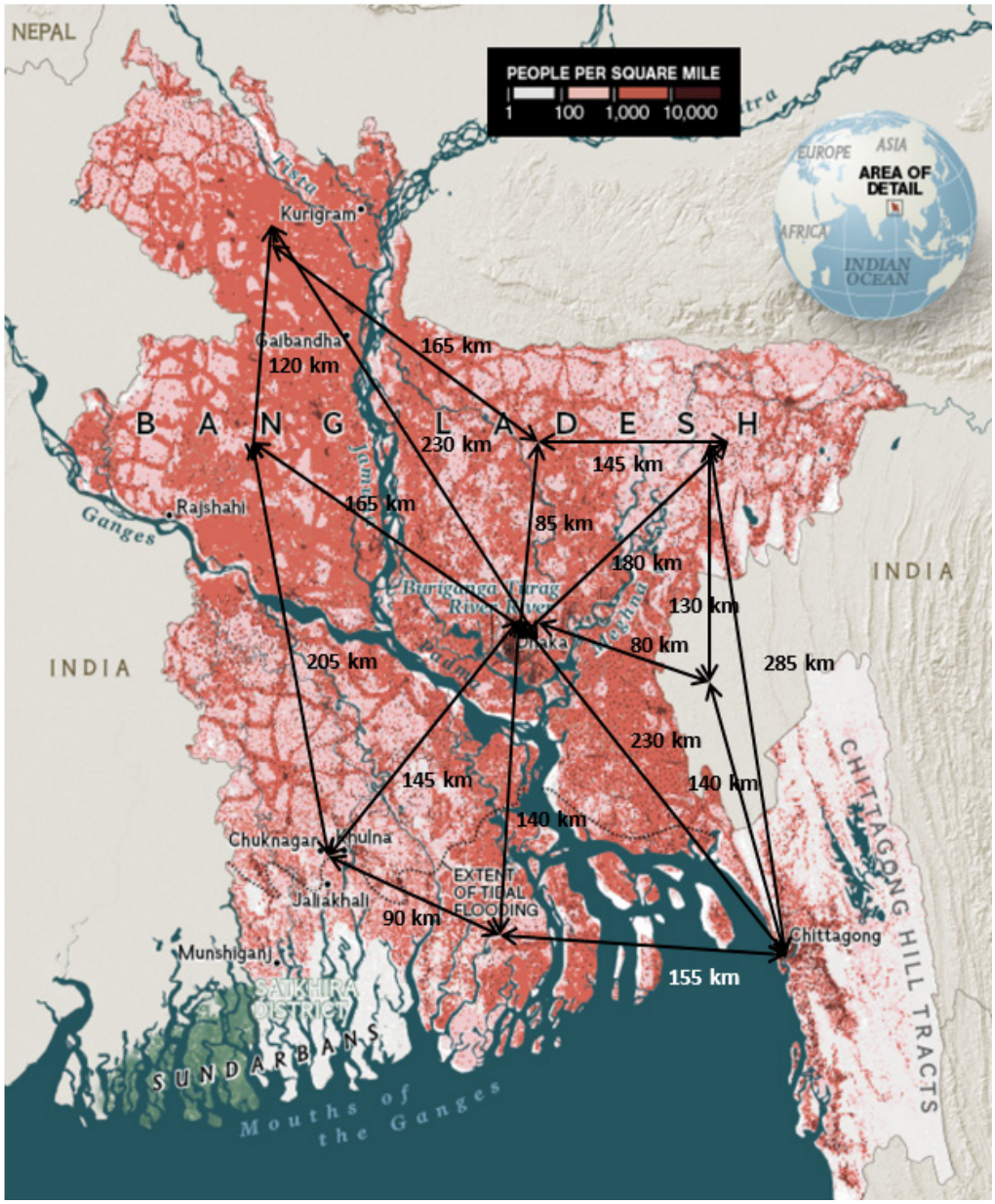
Ranking	FEMA building type, from most to least suitable
1.	13. Reinforced Masonry Walls - Flexible
2.	1. Wood Light Frame
3.	15. Unreinforced Masonry Walls
4.	2. Wood Frames, Commercial, and Industrial
5.	10.Concrete frames with infill Masonry Walls
6.	7. Steel Frames with Infill Masonry Walls
7.	14. Reinforced Masonry Walls – Stiff
8.	5 .Steel Light Frames
9.	4. Steel Braced Frames
10.	3. Steel Moment Frames
11.	6. Steel Frames with Concrete Shear Walls

Ranking	FEMA building type, from most to least suitable
12.	11. Precast/Tilt up Concrete Shear Wall Buildings
13.	8. Concrete Moment Frames
14.	9. Concrete Shear Walls
15.	12. Precast Concrete Frames

1.3.3 Importance of population density and region proximity

The next parameter to be considered is the effective proximity factor. This is a rough estimate of the influence neighboring regions have on each other found using the density of each region and the distance between them. Figure 6 provides the population density map for Bangladesh. The distances between the centers of each major division or region are also included in the figure.

Figure 6. Population density and distance between major regions (McNulty 2009b).



Using the distances between major regions along with the known density for any given region, the effective region proximity factor was determined. This factor is a rough estimate of the influence that neighboring regions have on each other, and it is found by using the density of each region and the distance between them. It was determined that the larger the effective proximity factor was between two regions, the greater influence they have on each other. Table 3 provides the effective proximity factors between all regions in this case study. Figure 7 provides a visual representation of the adjacent region's effective proximity factors. The density of each region is

listed at the endpoint of each arrow, whereas the effective proximity factor between two regions is located at the midpoint of each respective line. Figure 7 shows that the closer that two regions are to each other, the greater the effective proximity factor is.

Figure 7. Density and effective proximity factor (McNulty 2009b).

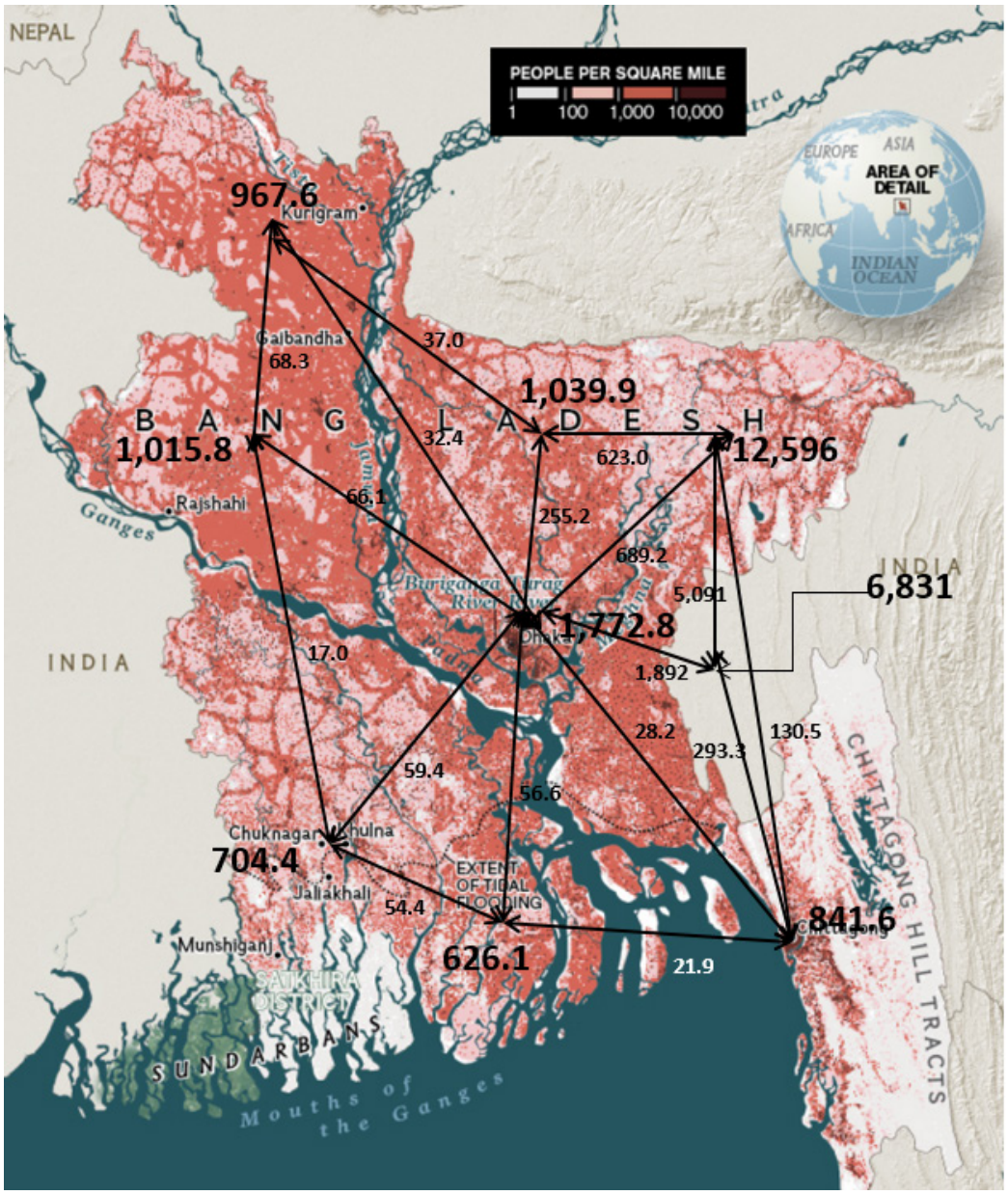


Table 3. Effective proximity factor between two major regions (McNulty 2009b).

Region 1	Region 2	Density Region 1 (people/sq. km)	Density Region 2 (people/sq. km)	Estimated Distance between Regions (km)	Effective Proximity Factor
Rangpur	Rajshahi	967.6	1,015.8	120	68.3
Rangpur	Dhaka	967.6	1,772.8	230	32.4
Rangpur	Mymensingh	967.6	1,039.9	165	37.0
Rangpur	Sylhet	967.6	12,596	280	155.5
Rangpur	Khulna	967.6	704.4	330	6.26
Rangpur	Barisal	967.6	626.1	360	4.67
Rangpur	Chittagong	967.6	841.6	460	3.85
Rangpur	Agartala	967.6	6,831	300	73.4
Rajshahi	Khulna	1,015.8	704.4	205	17.0
Rajshahi	Dhaka	1,015.8	1,772.8	165	66.1
Rajshahi	Mymensingh	1,015.8	1,039.9	185	30.9
Rajshahi	Sylhet	1,015.8	12,596	340	110.7
Rajshahi	Barisal	1,015.8	626.1	260	9.41
Rajshahi	Chittagong	1,015.8	841.6	400	5.34
Rajshahi	Agartala	1,015.8	6,831	280	88.5
Khulna	Dhaka	704.4	1,772.8	145	59.4
Khulna	Barisal	704.4	626.1	90	54.4
Khulna	Mymensingh	704.4	1,039.9	235	13.3
Khulna	Sylhet	704.4	12,596	330	81.5
Khulna	Chittagong	704.4	841.6	240	10.3
Khulna	Agartala	704.4	6,831	210	109.1
Mymensingh	Dhaka	1,039.9	1,772.8	85	255.2
Mymensingh	Sylhet	1,039.9	12,596	145	623.0
Mymensingh	Barisal	1,039.9	626.1	230	12.3
Mymensingh	Chittagong	1,039.9	841.6	305	9.41
Mymensingh	Agartala	1,039.9	6,831	135	389.8
Dhaka	Sylhet	1,772.8	12,596	180	689.2
Dhaka	Barisal	1,772.8	626.1	140	56.6
Dhaka	Chittagong	1,772.8	841.6	230	28.2
Dhaka	Agartala	1,772.8	6,831	80	1,892.2
Barisal	Chittagong	626.1	841.6	155	21.9
Barisal	Sylhet	626.1	12,596	280	100.6
Barisal	Agartala	626.1	6,831	155	178.0
Sylhet	Chittagong	12,596	841.6	285	130.5
Sylhet	Agartala	12,596	6,831	130	5,091.3
Chittagong	Agartala	841.6	6,831	140	293.3

1.3.4 Infrastructure

The next parameters that were examined were the travel infrastructure and other necessary parameters within the country of interest. Each figure provides a reference distance between a location on the map and the main city under consideration (Dhaka, Bangladesh is denoted by a yellow star). Figure 8 provides the locations of the major ports in and near Bangladesh. Figure 9 and Figure 10 provide the locations and distances between the centers of the railroad network and roadway network in each of the three main regions of Bangladesh, respectively. Next, Figure 11 provides the locations and distances between the major airports facilities within the country of Bangladesh. Lastly, Figure 12 provides the locations and distances between the centers of high flood-risk areas in Bangladesh.

Figure 8. Port map for Bangladesh ("Bangladesh Transportation" 2011).

Figure 9. Railroad network in Bangladesh ("Digital Chart of the World" 1993).

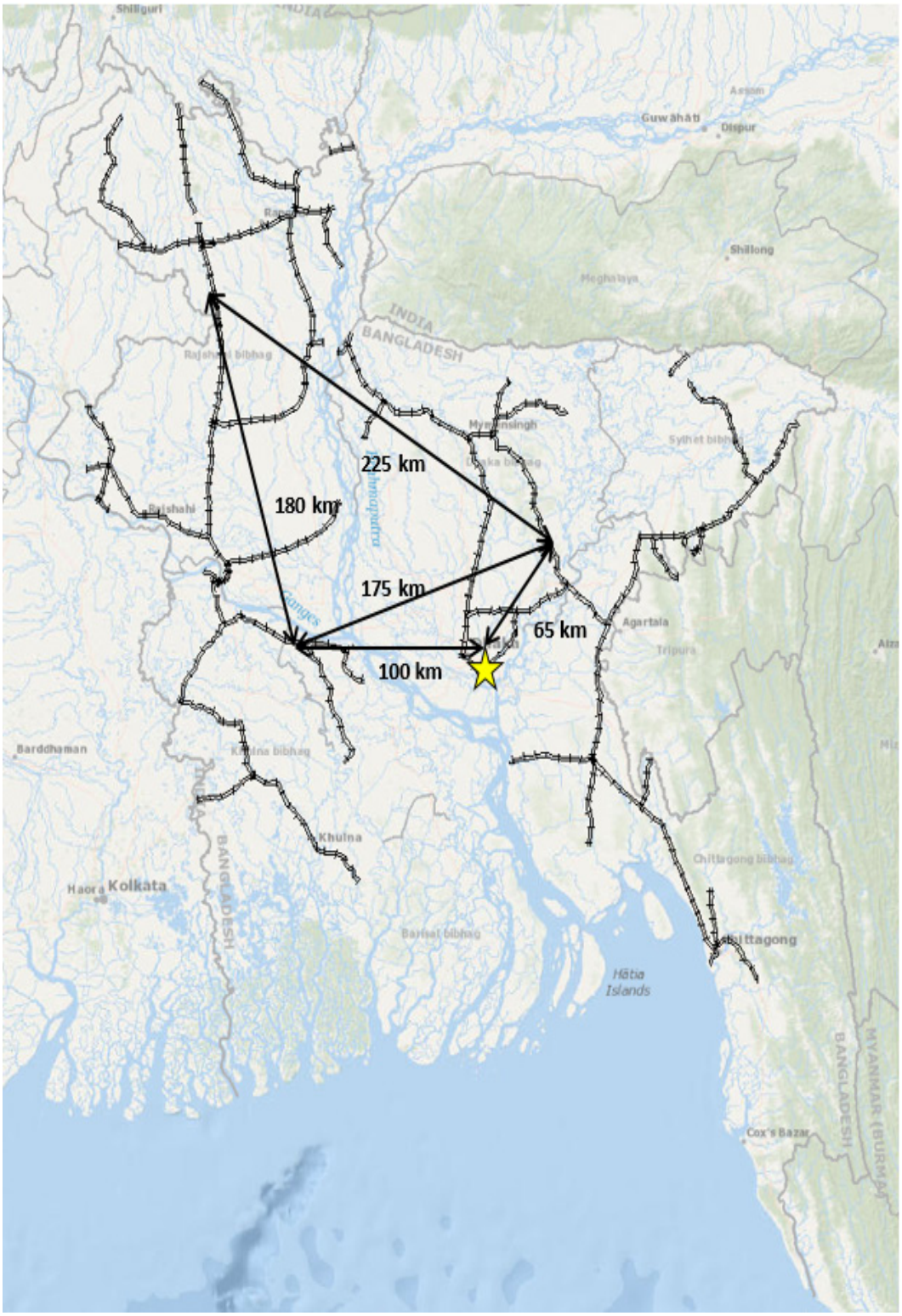


Figure 10. Road network in Bangladesh ("Digital Chart of the World" 1993).

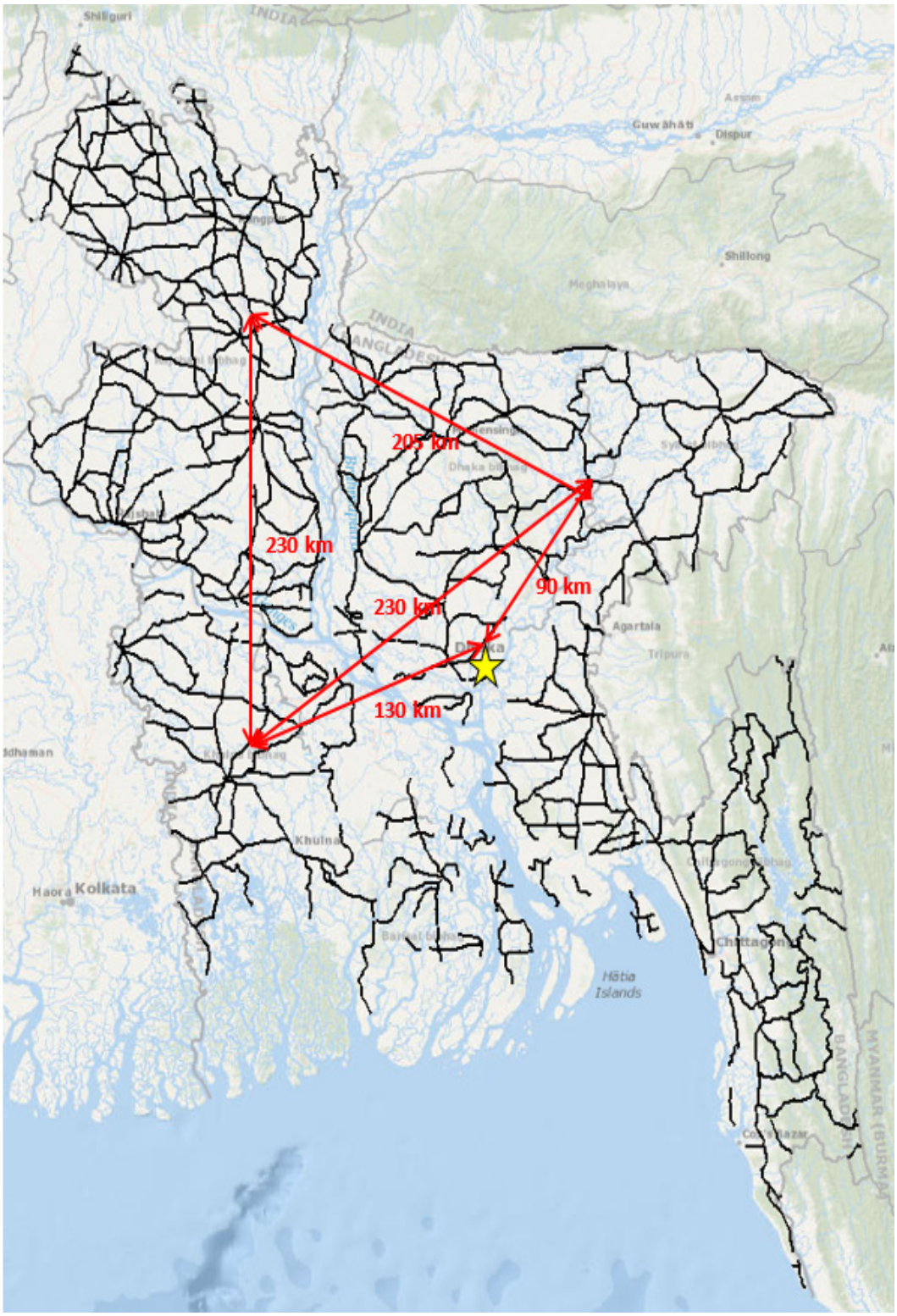


Figure 11. Airport facilities in Bangladesh ("Digital Chart of the World" 1993).

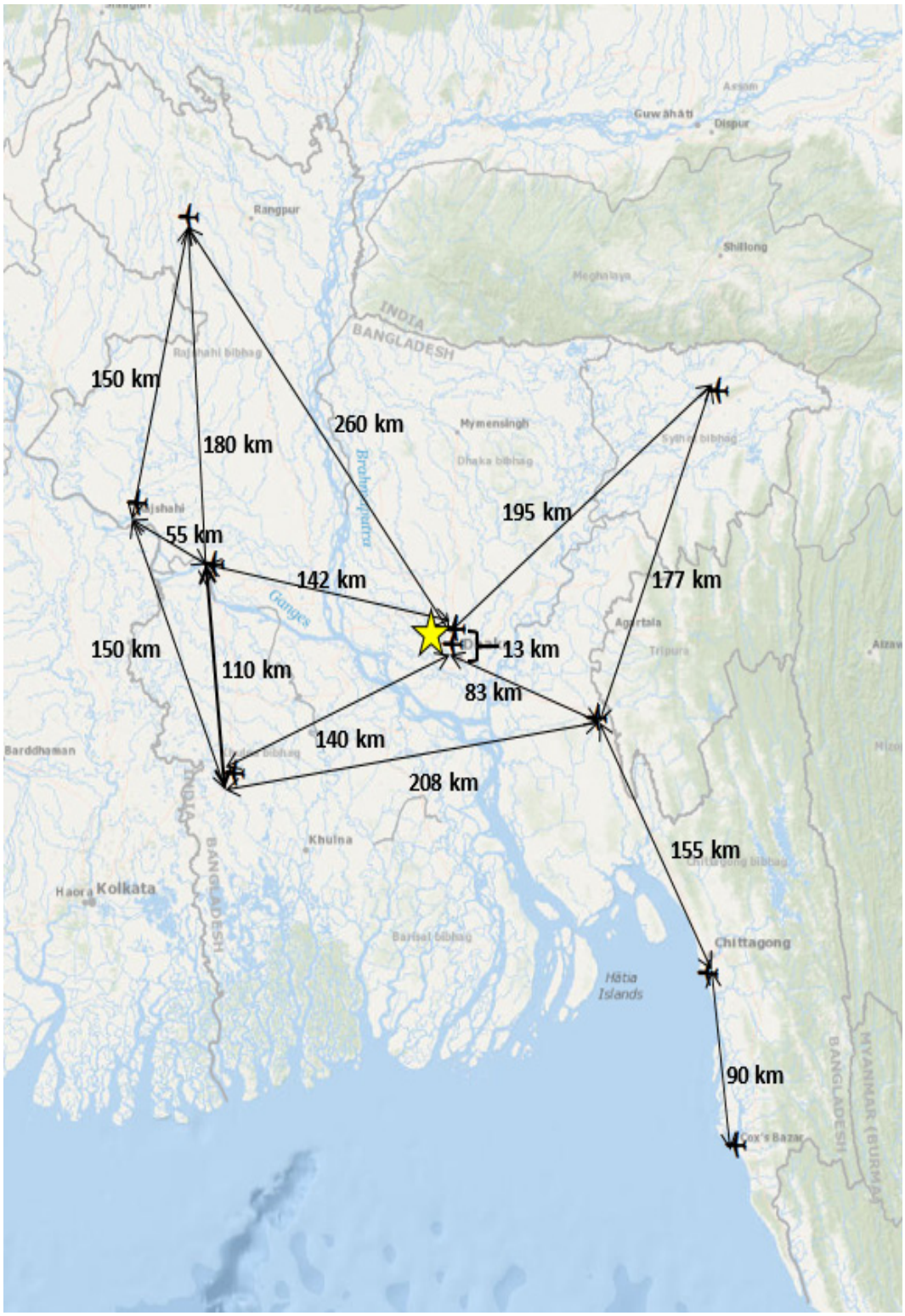
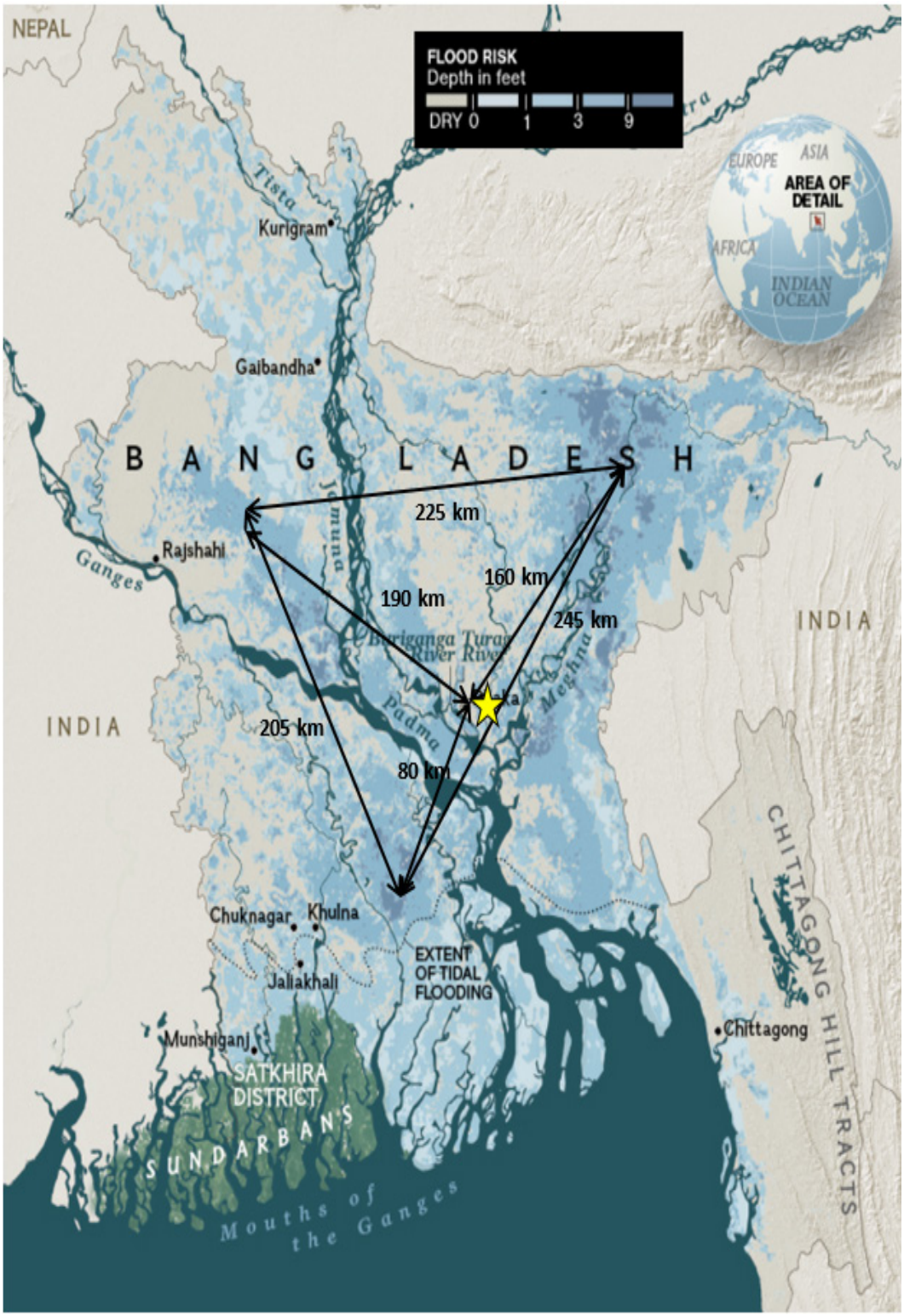


Figure 12. Flood-risk map for Bangladesh (McNulty 2009a).



1.3.5 Centers of construction resources

Upon determination of locations for various construction resources, the spatial data was used to infer the geographical centers for the various construction resources in each of the three regions. Figure 13–Figure 18 provide the geographical centers for the various construction resources in each of the three main regions from Figure 5. The construction resources are gravel, cement, ready-mix concrete, lumber, steel, and brick. In some cases, there are multiple central areas in a given region if a particular industry is very large in that region. For other construction resources, there may not be a geographical center for a particular resource in that area if the resource is not heavily or widely produced there.

Figure 13. Geographical center, gravel factor ("Bangladesh Transportation" 2011).

Figure 14. Geographical center, cement factor ("Bangladesh Transportation" 2011).

Figure 15. Geographical center, concrete factor ("Bangladesh Transportation" 2011).

Figure 16. Geographical center, lumber factor (“Bangladesh Transportation” 2011).

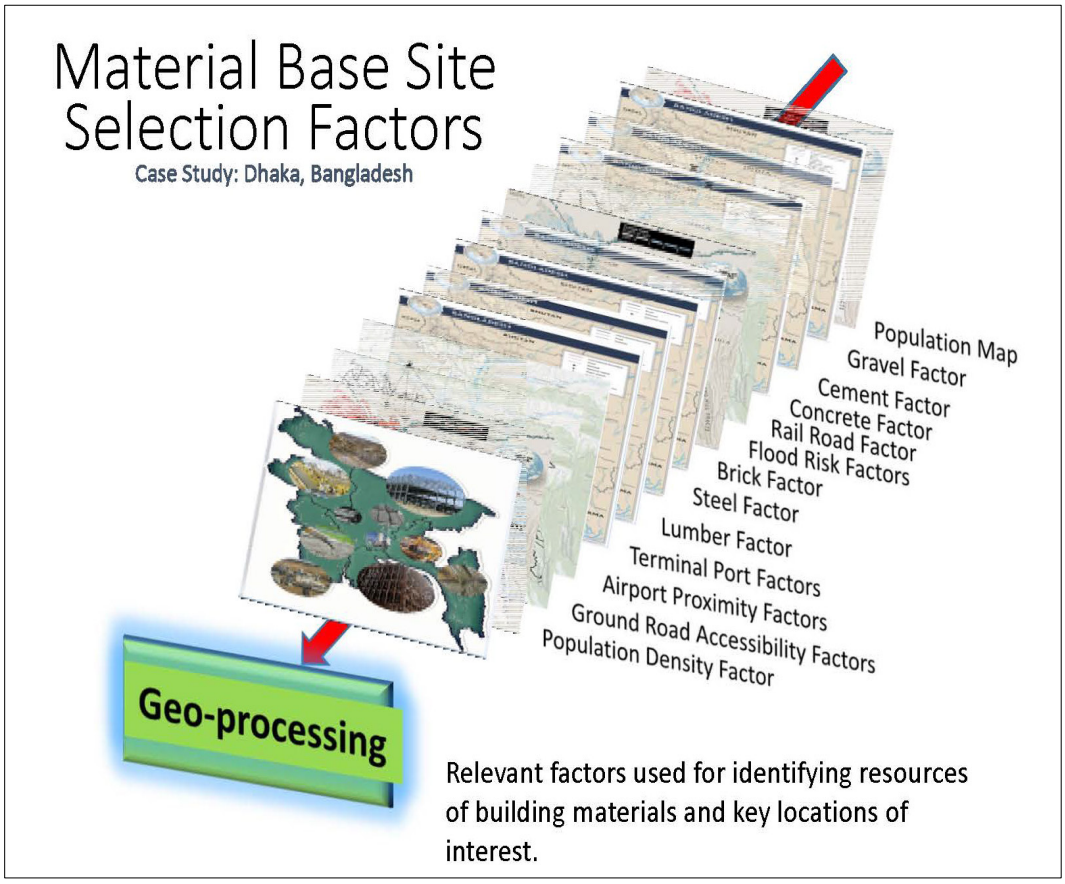
Figure 17. Geographical center, steel factor ("Bangladesh Transportation" 2011).

Figure 18. Geographical center, brick factor ("Bangladesh Transportation" 2011).

1.3.6 Construction resource for each region

Using the above information, the most widely available and used construction resource for each of the three regions was determined. Figure 19 provides a visual representation of the overlay of each of the important figures from above that was used in part to determine the most suitable construction resources for each region.

Figure 19. Overlay of site selection construction material factors (ERDC-CERL, 2016).



The possible construction resources included: concrete, lumber, steel, and brick. The ranking of feasibility for each resource in each region are listed in Table 4. It should be noted that the various construction resource industries may be seasonal in nature due to climatic conditions. Therefore, Table 4 is for optimal conditions, with no limitations to any of the construction resource industries.

Table 4. Suitability of construction resources for various Bangladesh regions (ERDC-CERL, 2016).

Region	Most Suitable Construction Resource	Second Most Suitable Construction Resource	Third Most Suitable Construction Resource	Least Suitable Construction Resource
1. Northeast Bangladesh	Brick	Lumber	Steel	Concrete
2. Southeast Bangladesh	Brick	Steel	Lumber	Concrete
3. Northwest and Southwest Bangladesh	Brick	Concrete	Lumber	Steel

Due to the wide availability of bricks throughout the region, this construction material was determined to be the most suitable construction resource for all three regions. However, the brick industry is seasonal in nature due to the wet season. As such, the second construction resource for each region must be considered when selecting a military base. Concrete was determined to be the least suitable construction resource for the regions not containing Dhaka, because the case study limited the determination of concrete production facilities to the areas in and around Dhaka, Bangladesh, since the construction resource is time-sensitive in nature.

1.4 Approach

1.4.1 Regions

As part of the research on the construction material industry in Dhaka, determining what geographical spatial data is pertinent to include in the study was investigated. The regions of interest for each raw and fabricated material were decided based on assumptions of how the material is transported and what data was feasible to collect. The regions of interest and study areas for each construction resource are shown in Table 5.

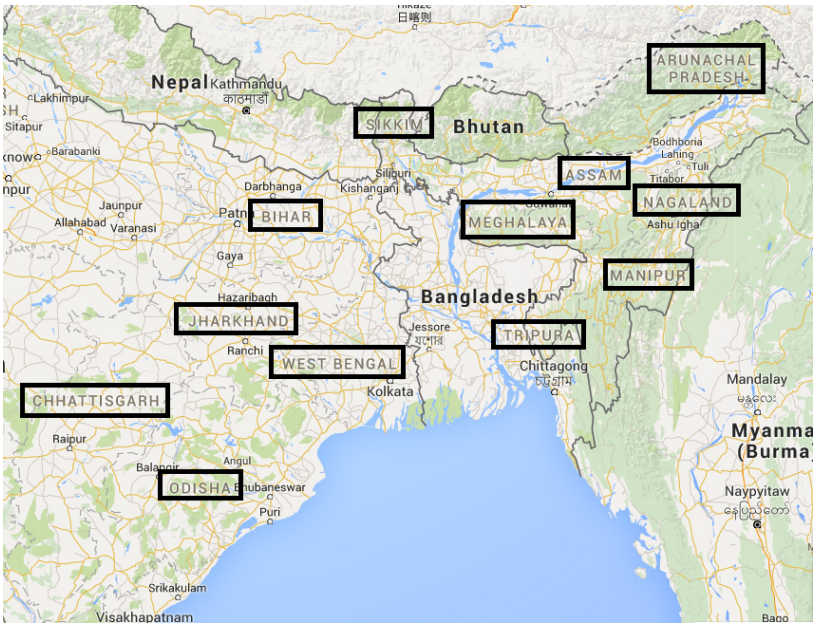
Table 5. Construction material study areas (ERDC-CERL, 2016).

Industry	Region of Interest	Reason for Study Region
Cement, aggregate, steel, iron ore/ recycled steel	Bangladesh, northeast India, and Myanmar	Key players can be easily assessed within study area
Wood, masonry	Bangladesh	Larger number of producers
Ready-mix concrete	Dhaka region	Time-sensitive product

For instance, ready-mix cement is a time-sensitive product that is used within a short distance of its source. Therefore, the study for the material was limited to the city of Dhaka. Cement, aggregate, steel, and iron ore were given a much wider area of interest that includes all of Bangladesh as well as the bordering countries of India and Myanmar. The studies on timber and masonry were limited to the country of Bangladesh due to the exceedingly large number of fabricators within the country (greater than 5,000 producers for each industry).

Due to the size of India, the study was limited to the eastern and northeastern regions under the assumption that most trade and general interaction with Bangladesh is within close proximity to the country. The regions of interest for India are provided in Figure 20 and indicate the major east and northeast regions within India. The larger regions within the country are indicated for reference.

Figure 20. East and northeast regions of India (Google Maps, 2016).



1.4.2 Sites

Construction materials are part of an interconnected network of resources, which results in movement from one point to another along the production process. Therefore, it is important to consider sites within the industry that are critical for research. The following key areas were researched as part of the spatial data analysis for each construction material:

- *Corporate offices*, which are an important part in the control and operations of processing. This category omits offices specifically for sales.
- *Plants, factories, and other manufacturing sites* ,where raw materials are transformed into the final product.
- *Terminals and shipping ports,* where the product is stored for future distribution as well as where the product is imported or exported.
- *Mines and raw material deposits*, where raw materials are extracted or available for excavation.

1.4.3 Material database assumptions

The materials database is a collection of the various construction resources' availability by location, quantity, type of material, etc. The database includes materials such as concrete, timber, and steel, among others. Tables A2-A22 in the Appendix provide each respective materials portion of the materials database, with pertinent information for that material included.

For natural resources, research was conducted on both currently exploited resources as well as reserves of resources. In the case of reserves, the feasibility for excavation was disregarded. If the reserves were present in a particular area, they were included in the collected information. There were also assumptions made based on the available information for raw material deposits. Whether or not these material deposit locations are suitable for construction purposes was absent from a number of sources, which may lead to extraneous data in the collected information.

For production plants, data was collected to represent the current status of operation. Data was only collected for currently operating plants, and only installed capacity information was collected. If a company has expected new plants or capacity gains over the coming years, this information was disregarded when creating the material database.

1.4.4 Spatial data

Three different types of spatial data were collected for each of the construction materials of interest.

The first type of data are specific and exact site locations. This latitude-longitude coordinate pair will spatially represent what it describes with precision. However, because the preciseness of material sites may vary based on available information, some information may be limited to a much broader area such as a city or a region, which is what the second type of data aims to represent.

The second type of data are approximate locations of individual sites based on limited information. Lastly, if information on individual sites are not provided, but data representing a larger area is given, then the third type of data is used. It is also important to note that point data are used to capture lines and shapes in addition to specific locations, which is a greater concern for geographical areas of interest such as mountains or rivers. In those cases, a single pinpoint may not accurately represent the data. In some cases, multiple approximate pinpoints are used when expressing the location. The extent of research on spatial data for Bangladesh and its surrounding countries was limited to the extent of available information. For instance, because of differences in the political system for each of the countries studied, the availability of government information on products and raw materials may vary.

The third type of data are a cluster of sites that represent the characteristics of what is contained within the region.[1] Cluster sites are also created based on researched information for each material, in order to quantify the behavior of the industry within centers of activity.

Within the material database, these data types are categorized as the following:

- **S:** the latitude-longitude coordinate pair that represents the exact site location.
- **A:** an approximate location of an individual site provided as a latitude-longitude coordinate pair, which may be represented by a region or city if limited information is available.
- **C:** a cluster of sites to represent the characteristics of a region or city, represented as latitude-longitude coordinate pair.

Spatial data has been represented using decimal degrees with the WGS84 Web Mercator projection.

1.4.5 Data sources

1.4.5.1 Suppliers

Material suppliers were originally established by using any available published resources about the material industry sector. Through a search on Google for the industry, reports and government databases on prominent companies and their respective plants were identified with additional information such as capacity, employees, and power usage. The success and total available information varied, based on the material and country. For instance, cement was the most widely available in reports, ready-mix concrete and steel had a fair amount of information, and timber was very limited in industry information. At the same time, published resources on materials were mostly available for Bangladesh and India, whereas reliable data for Myanmar was limited. For each of the resources, locations were then validated and a number of spatial data sources were appended to this data.

[1] If a cluster point is superimposed over a region with site or approximate data points, then the points are to be considered exclusive from one another.

One of the major sources of spatial data and company identification was Google Maps. Searches for materials using Google Maps unveiled various established locations, including corporate offices, plants, and mines. Precise coordinates of sites are reliable through this approach; however, the accuracy for smaller-scale company sites was somewhat questionable because data was usually limited to a name and a location. If these sites did not represent what they described visually, then the data was disregarded. This method was used for all materials except natural resource deposits.

Wikimapia was additionally used for spatial data of plants and mines. Through this method, boundaries of sites are clearly identified using the maps and usually presented more search results than Google Maps. The category of "production" was selected from the menu, which helped filter the points of interest. Similar to Google Maps, precise coordinates were very reliable, but smaller-scale company locations were limited in information and judgment was used as to whether data was pertinent to include. This method was used for all materials except aggregates, wood, and ready-mix concrete.

GIS data resources were used for spatial data of mines, natural resource deposits, and very minimally for plants. The United States Geological Survey (USGS) provided an abundance of GIS data for usage. The data itself was very plentiful, yet certain items were deemed unreliable due to the publication date. Many of the locations did not fully reflect what was described by the data and so, approximate data points were used. However due to the number of data points and clusters of points, it was still possible to determine centers of activity. Capacity data was discarded due to the outdated information presented.

After spatial data sources were exhausted, company websites were used to fill in the gaps in data and to find remaining locations of material sites. The amount of information provided on the company website varied significantly. However, almost all of the company websites list corporate offices, and a significant portion provided plant locations. A fair number of company websites provided addresses which were untraceable in Google Maps, and so approximations for locations were made. Other pertinent data was found by using these websites, including capacity, quality, product, employees, and power usage. A number of the larger-scale companies produce multiple construction materials and therefore, data overlapped

for various construction materials. This method was used for cement, ready-mix concrete, steel, and some raw material.

Lastly, material supplier directories were utilized for additional information. For some directories, such as Cemnet for cement or Fordaq for timber, this data was reliable but limited to companies that are a part of the collection. Other directories proved to be very unreliable since many of the companies listed may represent another line of work, such as material traders, or they may be out of business. It proved to be impossible to validate this information because company websites or other reliable sources were unavailable. The company addresses listed were also unreliable and varied across multiple directories. This method was used as a last resort, but it was used extensively for timber, and somewhat for cement and ready-mix concrete.

1.4.5.2 Industry

Industry information for construction materials was initially determined through the material industry sector search described previously by using a Google search. The number of reliable published reports discovered varied based on the material. Cement and timber (specifically the forestry aspect) provided the most information. Other technical reports and studies were discovered through the ScienceDirect database. For all materials considered, standards and methods originate from the Bangladesh National Building Code (BNBC-2014) and Technical Specifications for Buildings (2005).

2 Cement

Cement is a mixture used in the production of concrete. The dominant cement agent used in concrete production is Portland cement, which is a fine ground powder that is a mixture of limestone, shale or clay, gypsum, fly ash, and slag.[2]

2.1 Industry

2.1.1 Global scenario

Cement is an important contributor to the development of the economy of a country as it contributes to growth and urbanization. Global cement production has been increasing due in part to rising investments in infrastructure in developing countries. A report from the International Cement Review states that global demand of cement is 3.7 billion metric tons per annum (MTPA) for FY2012, which is almost double the demand a decade earlier of 1.8 billion MTPA for FY 2002. The current production and capacity is 4.2 billion MTPA for FY2014. The world production is dominated by China, followed by India. In total, China and India account for over 50% of cement production and consumption (Hossain 2015). The largest producers and competitors among the various global markets are Lafarge-Holcim (a recent merger of the French Lafarge and Swiss Holcim), and Cemex (USA). As a product, cement is a regional commodity because of variation due to supply-demand, per capita income, and level of industrial development (Hossain 2015).

2.1.2 Background

The cement industry in Bangladesh is the 40th largest in the world. The industry made its start in 1994: the year which the government began to allow cement factories under private ownership. Prior to 1994, the demand for cement products was fulfilled entirely by imported cement bags. Currently, the cement industry is expected to grow by 20%–25% in the medium- to long-term range. Within Bangladesh, cement is freight intensive, seasonal, and regional in nature (Nahar 2011).

[2] Britannica Academia, Online ed., s.v., "Cement." Accessed 15 January 2016. http://www.britannica.com/technology/cement-building-material

2.1.3 Seasonality and cyclicality

The cement industry in Bangladesh is heavily influenced by the yearly monsoon season, which can affect production by as much as 50% of capacity. The peak season for demand of cement is during the dry season between late-September/early-October to late-April/early-May, during which demand from the construction sector increases and matches or exceeds the capacity of the industry. This increased demand encourages an increase in capacity for producers and the entry of new producers. During the monsoon season from late-May/early-June through late August/early-September, the demand declines or steadies because of the slowdown in construction activity. This slowdown also causes the capacity additions to exceed demand. There is also a cyclical industry due to the time lag between capacity build-up and cement demand. This time lag lasts for several years because it takes 2–2.5 years for new producers to build a cement plant (Nahar 2011).

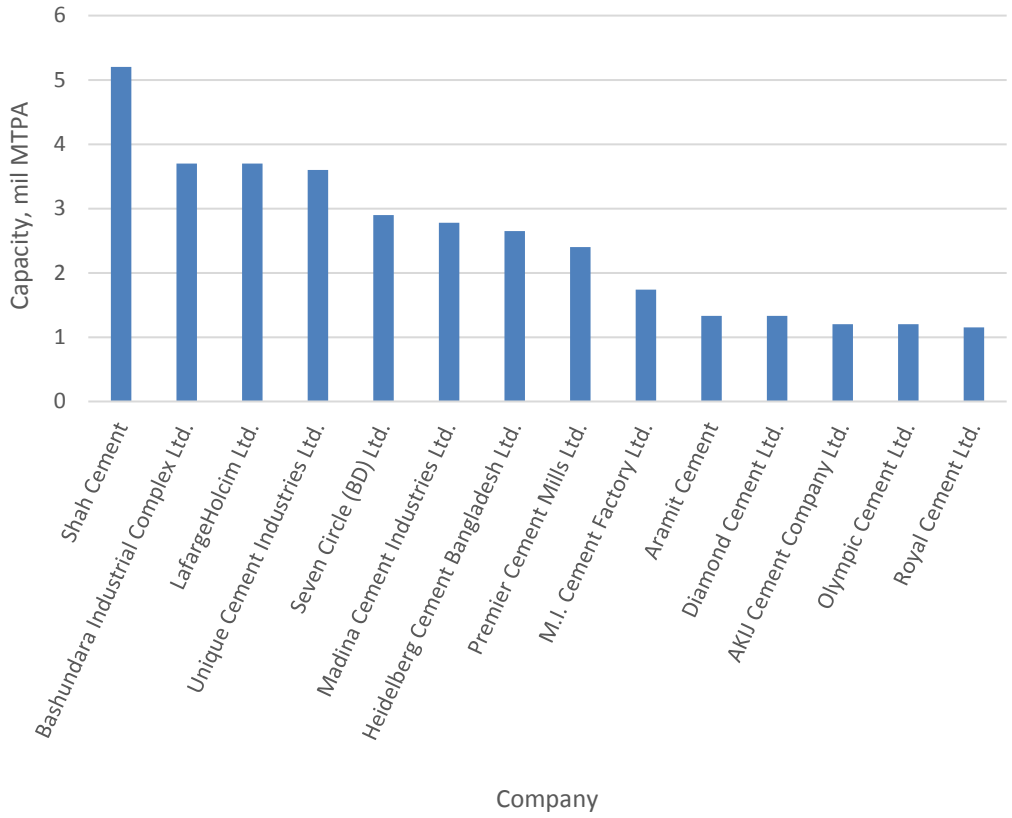
2.1.4 Producers

There are currently 124 companies in Bangladesh manufacturing cement. A total of 63 of these companies have production capacity and 32 are currently in operation. Of all the cement companies in Bangladesh, 27% are multinational companies while 73% are local manufacturers (Hossain 2015).

Within Bangladesh, the total cement capacity is estimated to be 36 million MTPA in FY 2015. Generally, larger companies have tended to outperform smaller manufacturers due to shortage of raw materials at a competitive price. In 2009, the top 13 players controlled over 78% of the industry and in 2013 85% of the industry was controlled by the top 10 players (Nahar 2011; Hossain 2015).

The top 14 companies and their installed capacities are shown in Figure 21. The figure was formed from a collection of capacities of cement companies from a variety of data sources within the material database. These data sources are included within the database itself.

Figure 21. Capacity of prominent cement producers in Bangladesh, FY2015.[3]



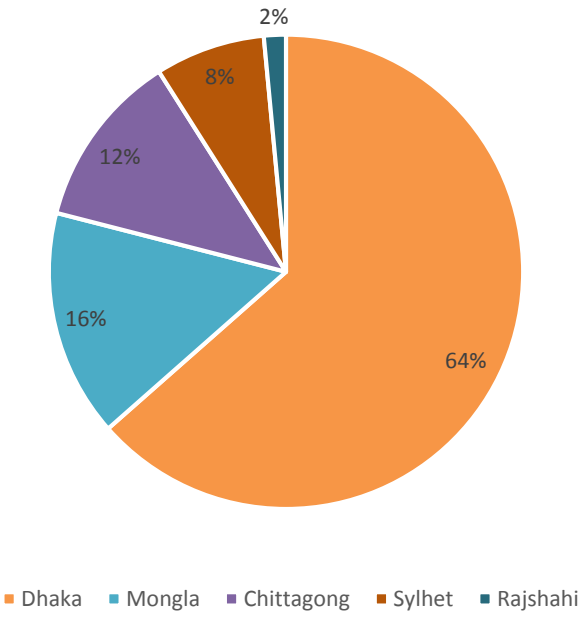
2.1.5 Consumers

The per-capita consumption of concrete in Bangladesh is small compared to surrounding countries. Bangladesh itself has a per capita consumption of 107 kg, compared with 210 kg in India (Hossain 2015). Cement products are consumed by three major groups, with the largest contributor being the government organizations. Individual homemakers consume 25%, real estate developers consume 35%, and government organizations consume 40% (Nahar 2011).

Cement is a regional product in Bangladesh because transportation over long distances increases the cost. Within each region, there is variation due to supply-demand, per capita income, and level of industrial development (Nahar 2011). The area-wise consumption of cement is shown in Figure 22. The Dhaka area represents the largest consumer of cement within Bangladesh.

[3] Capacity data is limited to companies with published production data.

Figure 22. Area-wise consumption of cement, FY2010 (Nahar 2011).[4]



2.1.6 Locations of construction material in Bangladesh

Cement is a regional product within Bangladesh, which is shown within the country through the clusters of cement sites in cities and along waterways, the largest of which include Dhaka, Chittagong, and Khulna, as shown in Figure 23. As the center of urbanized life and capital city of Bangladesh, it is expected that a large cement activity occurs within the city of Dhaka, which is shown in detail in Figure 24. Almost all of the corporate offices for cement production are located within the city of Dhaka, while the plants themselves are located along the rivers of the area. From east to west, these include the Meghna, Shitalaksha, and the Madaripur Rivers. Plants are also located inland from the city of Ghorashal in the north to Narayanganj in the south.

Chittagong and Khulna also have a relatively large amount of activity because Bangladesh's largest trading ports are in each city. Within both cities, the corporate offices for cement production are located within the city center and the plants are located along water bodies. In Chittagong, these water locations include the Karnaphuli River in the east and the Bay of Bengal in the west. Spatial data for Chittagong can be found in Figure 25.

[4] The Mongla region refers to both Khulna and Barisal divisions, The Dhaka region refers to the Dhaka and Mymensingh divisions, and Rajshahi refers to Rajshahi and Rangpur divisions.

Within Khulna, cement plants are located along the Bhairab River, which combines in the south end of the city with the Rupsa River. Spatial data for Khulna can be found in Figure 26.

Figure 23. Overview of Bangladesh [green: office, orange: plant, blue: terminal] (Google Maps, 2016).

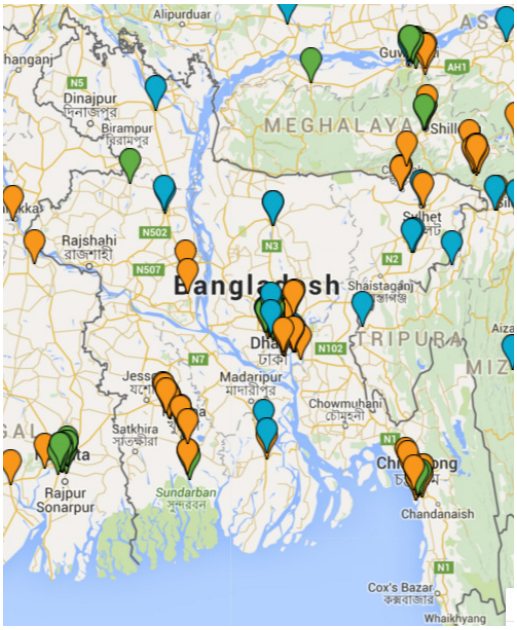


Figure 24. Dhaka area [green: office, orange: plant, blue: terminal] (Google Maps, 2016).

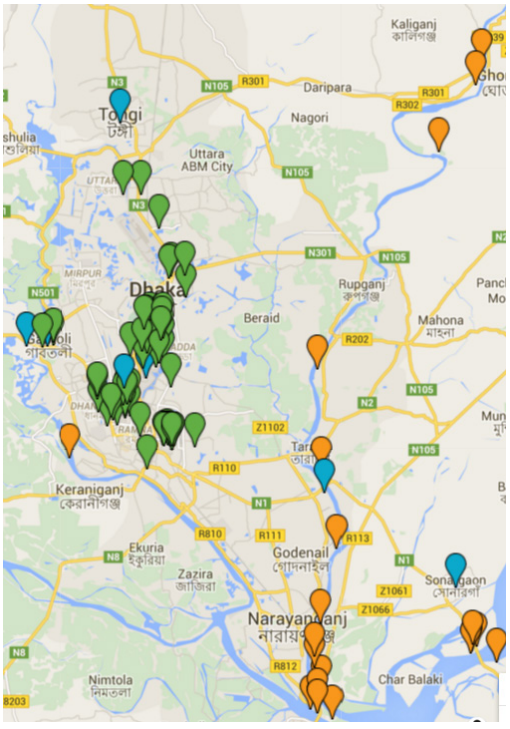


Figure 25. Chittagong area [green: office, orange: plant] (Google Maps, 2016).

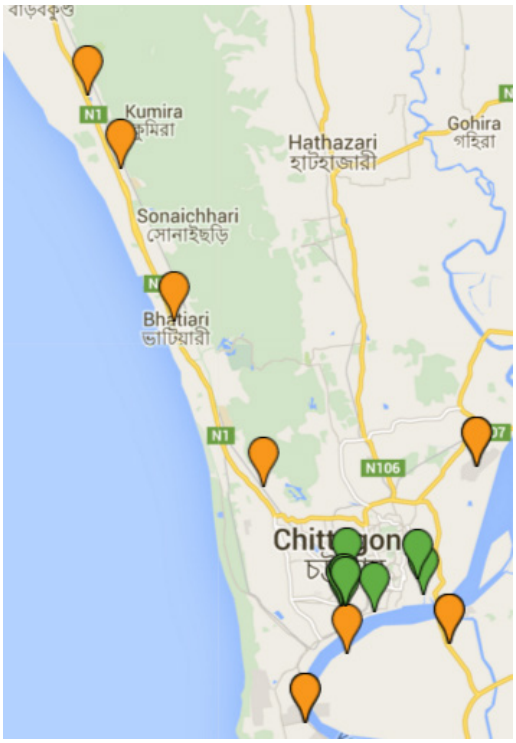
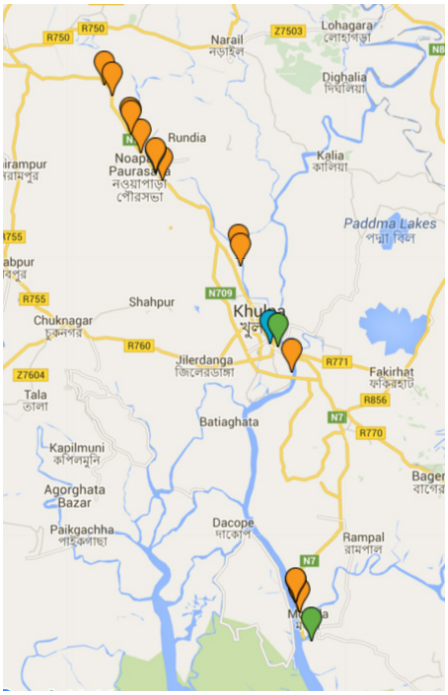


Figure 26. Khulna area [green: office, orange: plant] (Google Maps, 2016).



2.1.7 Construction material industry in India

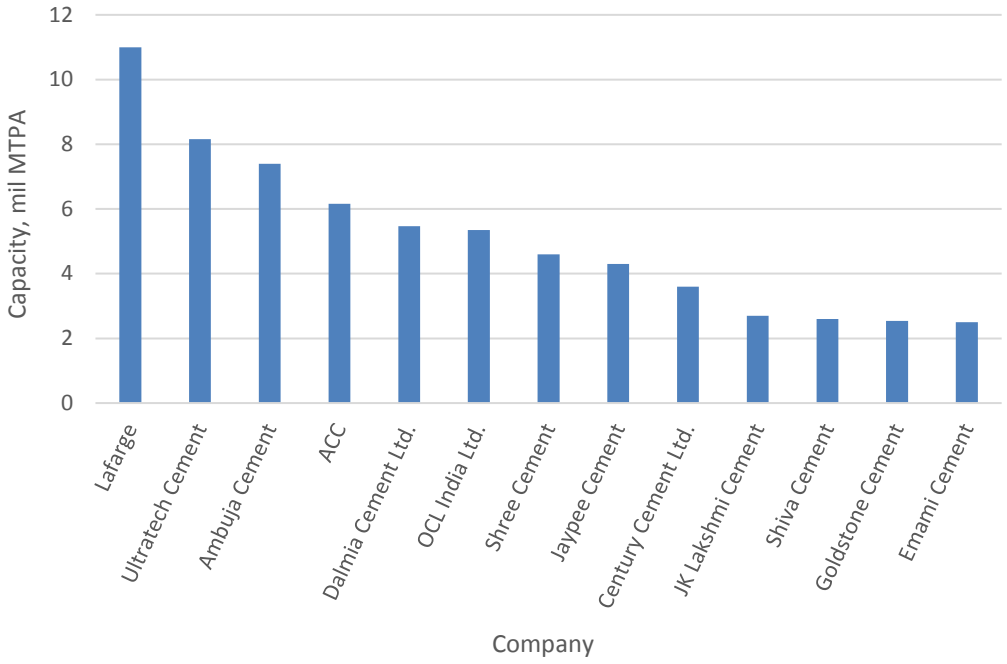
The Indian cement industry is the second largest cement market in the world behind China, with 390 million MTPA of production capacity. Production is expected to grow to 550 million MTPA by 2020. Cement production is used 98% in the private sector and 2% in the public sector. Most of the demand for cement product in India is from the housing sector, which accounts for 64% of the total product use. Other uses include infrastructure (17%), commercial (13%), and industrial (6%) ("Cement" 2015).

Similar to Bangladesh, the largest cement companies account for a significant portion of production. The top 20 companies producing cement in India represent around 70% of production. There are approximately 188 large cement plants and 365 smaller plants ("Cement" 2015).

Cement is also a regional product in India, with the production and consumption concentrated within specific areas. The largest concentration of cement plants are in India's south and north in the states of Andhra Pradesh, Rajasthan, and Tamil Nadu ("Cement" 2015).

Concentrating on eastern and northeastern India, which share a border with Bangladesh, 13.7% of the country's production occurs in this region ("Cement Production India" 2014). Based on analysis of cement producers in the region from the material database, the 13 major players can be found in Figure 27. The largest company is Lafarge, which produces 11 million MTPA of cement.

Figure 27. Capacity of prominent cement producers in east and northeast India, FY2015 (ERDC-CERL, 2016).[5]



Unlike Bangladesh, cement within India is clustered by locations of limestone deposits in addition to rivers and cities. An overview of the locations of cement sites can be found in Figure 28 and Figure 29. The major cities within this region include Kolkata in East India and Guwahati in Northeast India, both of which are centers of corporate offices. These cities are shown in Figure 30 and Figure 32.

The closest cluster of cement plants to Bangladesh is the Jaintia Hills region of Meghalaya, which is located near the north border of the two countries, as shown in Figure 31. There are a number of limestone deposits in the area that allow the region to be ideal for cement production. The second closest cluster of cement plants is on the border of West Bengal and Jharkhand, in which plants are clustered along the Dhamodar River, as shown in Figure 34. This location is ideal because the river connects with the city of Kolkata, allowing for lower transportation costs when providing cement to this urban area. Another two clusters of cement plants include the Odissa and West Bengal border as well as in Chhattisgarh because of

[5] Capacity data is limited to companies with published production data.

the availability of limestone in these areas, as shown in Figure 33 and Figure 35.

Figure 28. East India overview [green: office, orange: plant] (Google Maps, 2016).

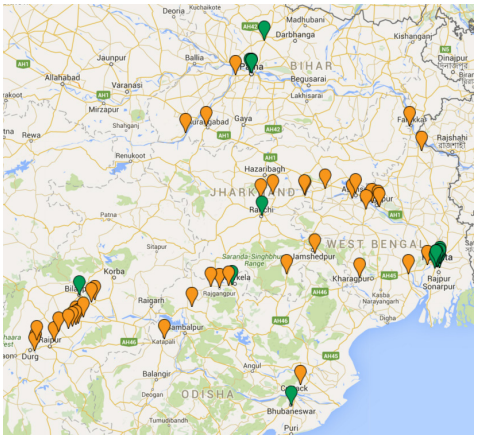


Figure 29. Northeast India overview [green: office, orange: plant, blue: terminal] (Google Maps, 2016).

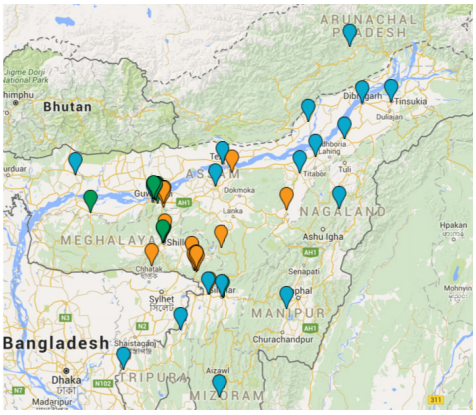


Figure 30. Guwahati area (northeast India) [green: office, orange: plant, blue: terminal] (Google Maps, 2016).

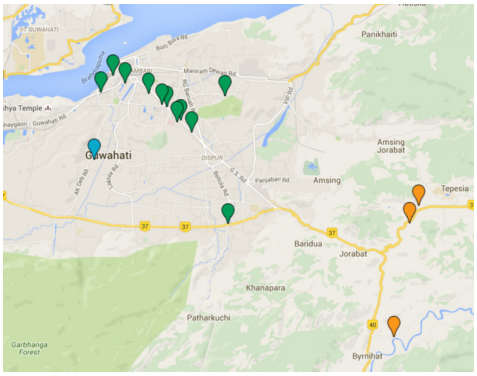


Figure 31. Jaintia Hills area (northeast India) [orange: plant] (Google Maps, 2016).

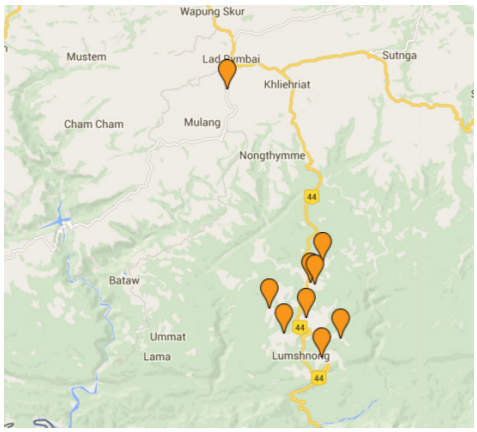


Figure 32. Kolkata area (east India) [green: office] (Google Maps, 2016).

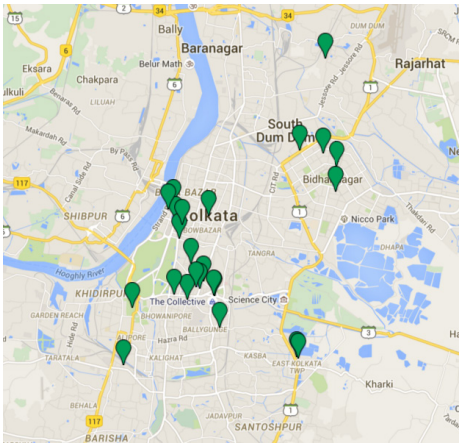


Figure 33. Chhattisgarh area (east India) [green: office, orange: plant] (Google Maps, 2016).

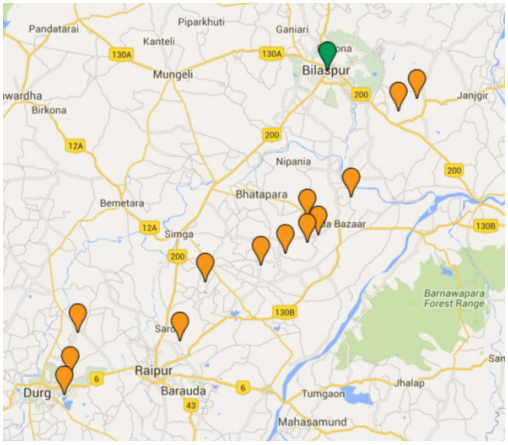
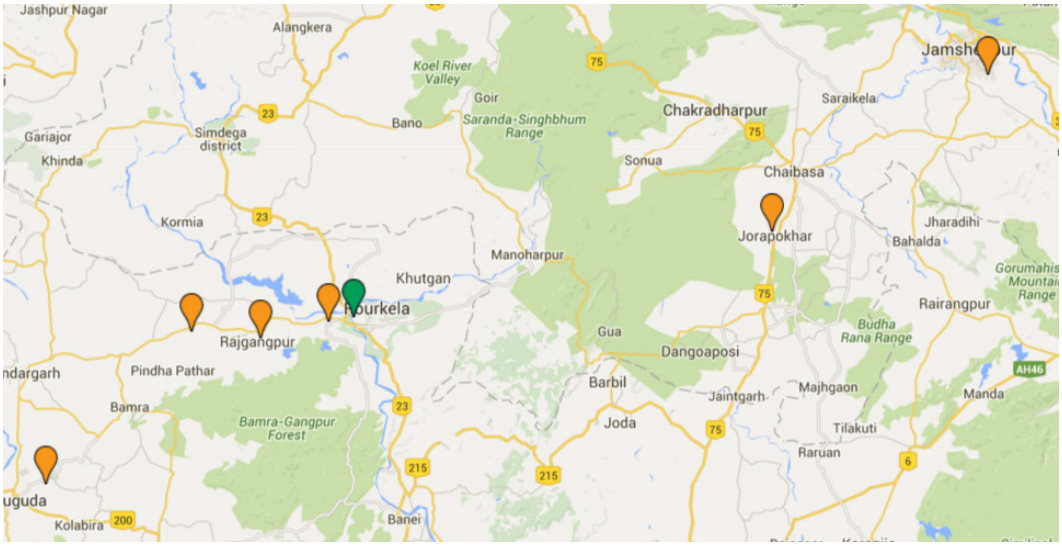


Figure 34. West Bengal/ Jharkhand border (east India) [green: office, orange: plant] (Google Maps, 2016).

Figure 35. Odissa/ west Bengal border (east India) [green: office, orange: plant] (Google Maps, 2016).



2.1.8 Construction material industry in Myanmar

Compared to India and Bangladesh, Myanmar has much smaller production of cement. Most of the cement activity is in and around the cities of Mandalay, Yangon, and Naypyidaw. Production is mostly controlled by government or semi-government companies. These companies include the following:

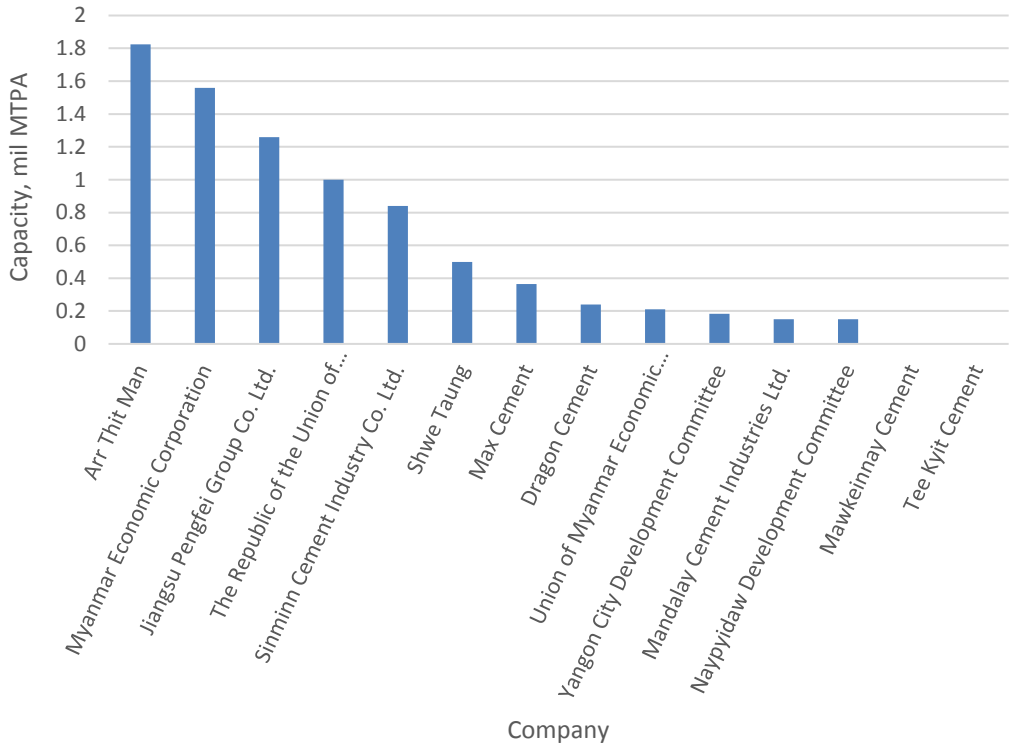
- Government
  - Ministry of Industry
- Semi-Government
  - Union of Myanmar Economic Holdings Ltd.
  - Myanmar Economic Corporation
  - Naypyidaw Development Committee

- Yangon City Development Committee
- Tee Kyit Cement Plant (USDA)

There are currently 13 active cement plants in Myanmar, providing a total production capacity of 5.36 MTPA in FY2015. However, the country is unable to operate at full capacity due to unreliable energy sources and lack of infrastructure. For instance, in FY2012 the production was 0.54 million MTPA despite the country having a 2.2 million MTPA capacity. The capacity of prominent cement producers in Myanmar is shown in Figure 36.

However, the industry is expected to grow significantly. There is a 1.8 million MTPA cement plant under Siam Cement's subsidiary Mawlamyine Cement Ltd. and a 2.5 million MTPA cement plant under Semen Indonesia currently under construction; both of these plants would be the largest producers in the country (Saunders 2015).

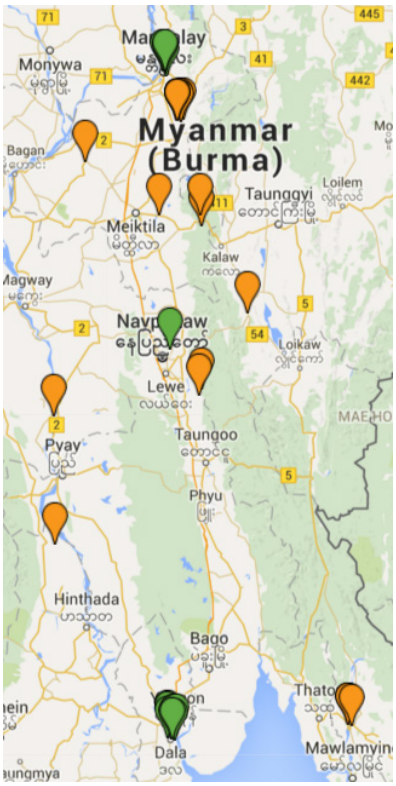
Figure 36. Capacity of prominent cement producers in Myanmar, FY2015 (ERDC-CERL, 2016).[6]



[6] Capacity data is limited to companies with published production data.

Figure 37 shows locations of cement sites within Myanmar. Cement locations are mostly in the center of the country. Corporate offices are centered in major cities, which include from north to south: Mandalay, Naypyidaw, and Yangon. Cement plants are around locations of limestone deposits and nearby cities to provide access to natural resources and lower transportation costs.

Figure 37. Myanmar overview [green: office, orange: plant] (Google Maps, 2016).



2.2 Product

2.2.1 Codes, standards, and methods

The government of Bangladesh requires concrete, constituent materials, methods, and procedures to conform to any of the standard specifications of ASTM (American Society for Testing and Materials), BS (British Standards), or BDS (Bangladesh Standards) (Technical Specifications for Buildings 2005).

Bangladesh follows the Bangladesh National Building Code (BNBC 2015), which was developed by the Ministry of Housing and Public Projects.

In order to market products in Bangladesh, the cement brand needs accreditation from The Bangladesh Standards and Testing Institute (BSTI) to ensure the quality, weight, and services of the product. The BSTI has adopted the European Norms (EN) titled as BDS EN 197-1:2003, or Cement Part-1: Composition Specifications and Conformity Criteria for Common Cement, which categorizes the types of cement. According to BDS EN 197-1: 2003, there are 27 products in the family of common cements, which are grouped into five categories for classification of cement based on the composition, these are CEM I, CEM II, CEM II, CEM IV, and CEM V (Nahar 2011). Details on the cement classification in Bangladesh are shown in Table 6.

Table 6. Cement classification (Nahar 2011).

Cement EU Standard and Composition			
	Types of cement	Clinker	Other Constituents
CEM I	Portland	95-100	
CEM II	Portland-slag	65-94	Blast furn. slag
	Portland-silica fume	90-94	Silica fume
	Portland-pozzolana	65-94	Pozzolana
	Portland-fly ash	65-94	Fly ash
	Portland-burnt shale	65-94	Burnt shale
	Portland-limestone	65-94	Limestone
	Portland-composite	65-94	Additives mix
CEM III	Blast furnace	5--64	Additives mix
CEM IV	Pozzolanic	45-89	Additives mix
CEM V	Composite	20-64	Additives mix

Source: www.cembureau.be

CEM I is given the title of Ordinary Portland Cement (OPC) because it has no Supplementary Siliceous Materials (SCM) such as fly ash, silica fume, slag, etc. The group CEM II, or Portland Composite Cement (PCC), is subdivided into different groups based on the mineral admixture and limestone powder used in production (Uddin et al. 2013). These additions replace a significant portion of the clinker in the product.

The following are the relevant standards for cement listed in BNBC:

- BDS 232 - Ordinary Portland Cement and Rapid Hardening Cement
- BDS 612 - Sulphate Resisting Portland Cement-Type A
- ASTM C150 – Portland Cement
- ASTM C595 – Blended Hydraulic Cements and others listed in ACI-318

2.2.2 Construction material

Globally, Portland cement is the most common type of cement used because modifications can be performed easily, depending on the process used to combine the components together (Hossain 2015).

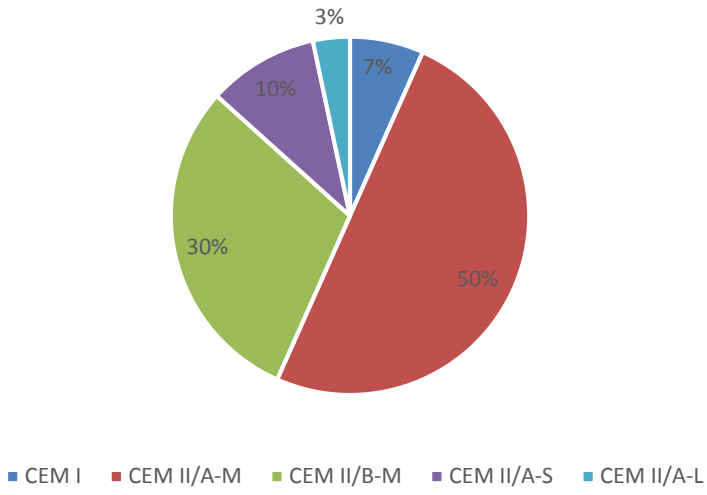
Prior to 2003, the only type of cement available in Bangladesh was OPC, which follows the standards set by the American Society for Testing and Materials (ASTM). In 2003, additional cement mixes became available in Bangladesh to make available an array of cement products to customers. The cement most used is PCC, which follows the European Standard Methods (ESM). This product is more popular because it requires less clinker (the largest component in a cement mix), has a greater environmental significance, and has a comparatively lower cost to produce (Hossain 2015).

Currently, Bangladesh only uses two types of cement product: OPC and PCC. The ratio of PPC to OPC production is 95:5 (Hossain 2015). The percent composition of materials for PPC and OPC per BDS EN 197-1 is represented in Table 7. According to a 2013 study on 30 cement bags of different brands within Bangladesh, the only types of cement present and in use for construction works in Bangladesh were CEM I and CEM II (Uddin et al. 2013). Figure 38 provides a visual representation of the 2013 study.

Table 7. OPC and PPC classification as per BDS EN 197-1 (Uddin et al. 2013).

Composition (%)	Type of Portland Cement				
	CEM I	CEM II/A-M	CEM II/B-M	CEM II/A-S	CEM II/A-L
Clinker	95-100	80-94	65-79	80-94	80-94
Blast-furnace Slag	-	6-20	21-35	6-20	-
Silica Fume	-			-	-
Pozzolana	-			-	-
Fly Ash	-			-	-
Burnt Shale	-			-	-
Limestone	-			-	6-20
Additional Constituents	0-5	0-5	0-5	0-5	0-5

Figure 38. Results on study of cement classification within Bangladesh, FY2013 (Uddin et al. 2013).



Within PCC, the preferred type of cement is the CEM II/A-M, which is composed of less mineral admixture than CEM II/B-M. This preference in product is due to customers' hesitance to use a cement with large amounts of minerals due to lack of advanced knowledge and low-quality mineral admixtures imported from abroad (Uddin et al. 2013).

2.2.3 Grade

In terms of compressive strength of cement mixtures, CEM I shows a relatively higher strength compared to CEM II. With increasing mineral content in cement, the strength difference is larger at an early age. The common grade for cement products in Bangladesh is 42.5N and 52.5N for CEM I and 42.5N for CEM II.7 It was also found that CEM II/A-S and CEMII/A-L show faster strength redevelopment compared to CEM II/A-M and CEMII/B-M (Uddin et al. 2013). Cement compressive strength also varies based on the preparation used to create the mixture.

2.2.4 Reported quality

Cement purchased directly from a manufacturer is typically better quality than that acquired from a local dealer or street market. Other factors in the quality of the cement include the storage of the cement at the construction site and the brand name of the product. From a study of 135 samples of CEM I mixture from construction sites in Dhaka in 2001, no test satisfied

[7] With increasing grade, the cement has a higher compressive strength.

the standard compressive strength for 28 days; however, 53.33% of samples showed strength within 90% of the specified strength (12.4 MPa), and 80% of samples show strength within 75% of the specified strength for 3 days. It was estimated that the 28-day strength is attained in 90–100 days. Due to this variability, cement product should be tested regularly. To satisfy this need, the Dhaka Engineering Department of the People's Republic of Bangladesh has established quality control laboratories with modern testing equipment (Koehn 2001).

2.2.5 Product in India

The relevant standard for production of cement is set by the Bureau of Indian Standards (BIS). The following are the relevant standards for cement, as listed in BIS:

- IS 269 – Ordinary Portland Cement Grade 33
- IS 8112 – Ordinary Portland Cement Grade 43
- IS 12269 – Ordinary Portland Cement Grade 53 and 53-S
- IS 1489 Pt. 1-2 – Portland Pozzolana Cement
- IS 455 – Portland Blast Furnace Slag Cement
- IS 12330 – Sulphate Resistant Portland Cement
- IS 8041 – Rapid Hardening Portland Cement
- IS 12600 – Low Heat Portland Cement
- IS 3466 – Masonry Cement
- IS 8043 – Hydrophobic Cement

Similar to Bangladesh, India mostly produces two types of cement product: OPC and PCC. Because of the high availability of fly ash from thermal power plants and the use of more advanced technology, there is a greater production of PCC. Only 31.6% of production is OPC. PCC can be divided into Portland Pozzolana Cement, which is 61.2% of production and Portland Blast Furnace Slag Cement, which is 6.9% of production. The common grades for cement in India include 33, 43, 53, and 53-S. 53-S is a grade specifically made for production of railway sleepers ("Cement" 2015).

2.2.6 Product in Myanmar

A large portion of the cement is imported, mainly from Thailand, Indonesia, Malaysia, India, and Bangladesh because of undersupply, high prices

of domestic cement, and low-quality product. The undersupply, in addition to the high domestic prices, is due to the relatively small cement plants that characterize Myanmar. The low quality results from Chinese machines and spare parts that are used to replace German equipment and the unskilled cement plant workers with little knowledge of cement. This translates to a product with quality that is unsafe for construction (Saunders 2015).

2.3 Production factors

2.3.1 Raw materials

Raw materials account for the largest cost in the production of cement and represent 75% of the cost of sales. The main raw material used in production is limestone, which is around 70%–75% of the cost of goods sold. Bangladesh does not have an adequate limestone supply because the land is mostly composed of silt and sediment. Therefore, Bangladesh cannot produce clinkers within the country and is left to rely on imports. There are 10–14 million tons of clinker is imported annually, with more than 80% used in cement production.

The exceptions are the companies of Lafarge Surma and Chhatak Cement Factory Ltd (a limited-production government-owned company), which have clinker production facilities in Sylhet. Lafarge Surma is able to extract 2 million MTPA of limestone across the India-Bangladesh border via a conveyor belt that is 17.3 km long. In order to provide a quality that is agreeable to cement production, small amounts of shale are mixed in to condition the limestone. The governments of India and Bangladesh had signed an agreement in November 2000 in order to allow this cross-border commercial and industrial venture. The conveyor belt connects between a mine at Phlangkaruh, Nongtrai Shella Confederacy in the district of East Khasi Hills to the cement plant at Chhatak, Bangladesh. Lafarge Surma, in turn, produces 10% of the total clinker required for Bangladesh (Ghosh, Bose & Associates 2013).

2.3.2 Imports and exports

The total value in U.S. dollars of imports and exports of the raw materials used in the production of cement is shown in Table 8.

Table 8. Imports and exports of raw materials for cement, FY2013 (Simoes 2013).

Sum of Value	Material				
Country	Gypsum	Limestone	Slag and Fly Ash	Clinker	Grand Total
Export	**$ -**	**$ -**	**$ 26,019,200**	**$ -**	**$ 26,019,200**
Asia					
China	$ -	$ -	$ 19,760,000	$ -	$ 19,760,000
Japan	$ -	$ -	$ 6,240,000	$ -	$ 6,240,000
Europe					
Belgium-Luxembourg	$ -	$ -	$ 19,200	$ -	$ 19,200
Import	**$ 14,193,894**	**$ 31,026,088**	**$ 15,165,701**	**$ 405,025,600**	**$ 465,411,283**
Africa					
Egypt	$ -	$ 2,990	$ -	$ 406,000	$ 408,990
Asia					
China	$ 124,960	$ -	$ 5,290,221	$ 23,548,000	$ 28,963,181
India	$ 326,600	$ 30,478,000	$ 4,783,280	$ 6,902,000	$ 42,489,880
Indonesia	$ -	$ -	$ -	$ 16,646,000	$ 16,646,000
Japan	$ -	$ -	$ 4,920,000	$ 1,299,200	$ 6,219,200
Malaysia	$ 5,254	$ -	$ -	$ 6,090,000	$ 6,095,254
Oman	$ 170,400	$ -	$ -	$ -	$ 170,400
Pakistan	$ 22,720	$ 5,598	$ -	$ -	$ 28,318
Singapore	$ -	$ -	$ -	$ 974,400	$ 974,400
South Korea	$ 31,240	$ -	$ 172,200	$ 36,540,000	$ 36,743,440
Thailand	$ 13,490,000	$ 497,600	$ -	$ 48,720,000	$ 62,707,600
Vietnam	$ -	$ -	$ -	$ 263,900,000	$ 263,900,000
Europe					
Germany	$ 22,720	$ -	$ -	$ -	$ 22,720
Italy	$ -	$ 41,900	$ -	$ -	$ 41,900

At present, Bangladesh imports around $405 million per year in clinker (in 2013). Most of its clinker (96%) originates from Vietnam, Thailand, South Korea, China, and Indonesia; Vietnam is their major source. Only 2% is imported from India via railway. However, around 98% of limestone, the raw material for clinker, is imported from India.

Gypsum, which is another major component of cement's composition, is not available within the country and is imported mostly from Thailand (95% of Bangladesh cement production utilizes Thailand imports).

Slag and fly ash, which are waste products from the steel industry, are both available within Bangladesh and are exported more than they are used within Bangladesh. The major destination of export is China, which receives 76% of these products from Bangladesh. Bangladesh almost entirely imports its slag and fly ash from China, India, and Japan (Simoes 2013).

There are two main ports in Bangladesh: the Mongla Port and the Chittagong Port, which are located on the south end of the country. Most imported materials originating from India arrive at the Mongla Port and several land ports, whereas materials imported from other countries arrive in the Chittagong Port (Hossain 2015).

2.3.3 Technology

The following steps are the process followed in Bangladesh to produce cement through an integrated mill, which uses raw limestone as a raw material for production. Because of the limited availability of raw materials, the cement plants in the Bangladesh industry are 95% grinding plants and 5% integrated plants. Grinding plants start the production process at step 4.

1. Clinker is produced. The natural raw materials (i.e., limestone, chalk, shale, mill scale, and bauxite) are crushed into a fine powder in the correct proportions and blended to make "raw feed" or "kiln feed."
2. Before entering the kiln, a method of preparation is selected based on the moisture content of the raw material. The first method is the dry method, in which a meal is formed from the drying of the materials. The wet method is typically used when the moisture content is greater than 20%, in which case additional water is added to form a slurry. In Europe, the dry method is the most common process used in cement plants because the wet method requires 56%–66% more energy to create the end product. However, the wet method is what is typically used in Bangladesh.
3. This blend is then processed in a rotary kiln, where it is heated to 1,450 °C (2,642 °F) and very quickly cooled.
4. The clinker is then ground with calcium sulfates (gypsum) and with industrial process waste such as slag, limestone, and fly ash to make Portland cement (Hossain 2015).

2.3.4 Transportation and distribution

Cement has a high weight-to-price ratio, thereby affecting transportation cost which makes up 5% of the cost of sales of the product. Thus the cement plant's location with respect to its distribution terminal can be a factor in the price of a company's product.

A combination of distribution methods are used, including bulk and bags via road, rail, inland waterways, and by sea. Imports and exports of cement product are more feasible through connecting water bodies because of the lower cost and easier accessibility (Nahar 2011).

2.3.5 Power

Utility costs represent the second-largest portion of the cost of sales for cement, which is around 10%. It is estimated that 30–35 kW of electricity is needed to product a metric ton of cement. Most of the power requirement for cement plants is met through the national grid; however, companies with large capacities have transitioned to using captive power plants for energy. There are currently around 18 manufacturers in Bangladesh that have captive power plants. Using this method allows for continuous power supply for uninterrupted production as well as a reduction in utility costs (Hossain 2013).

3 Ready-Mix Concrete

Concrete is one of the oldest construction materials and is in use throughout the world for its functionality, accessibility, and cost. Concrete comes from the Latin word "concretus," which means "to hold together." That is, concrete is a formable rock. Concrete for construction is composed of a cement mixture, aggregate, water, and admixture. The material is used for structural applications including walls, columns, slabs, beams, foundations or as an architectural feature for curtain walls and decorative columns. The functions of concrete in building structures include insulation from environmental loads (precipitation, fire, wind, temperature, etc.), as well as low-maintenance and durable structural support.[8]

There are two main ways to mix concrete: in a batch plant off-site or by hand and/or a small machine mixer on-site. Ready-mix concrete is a type of concrete that is manufactured in a factory or batching plant according to a set recipe and then delivered to a worksite by truck-mounted transit mixers. The fresh concrete must be transported within the requisite travel time, which is typically 120 minutes after batching. As an advantage, ready-mix concrete plants in a centralized location can serve urbanized areas while eliminating or avoiding storage space, material waste, noise and dust pollution, and additional labor on-site. The solution reduces costs and provides a better quality of concrete. A disadvantage of ready-mix in a city is that it generates additional road traffic, and that access to roads and sites are restricted due to limitations in truck weight capacity (Jahid).

3.1 Industry

3.1.1 Global scenario

The ready-mix concrete market is expected to grow over due to the rising demand for the product in the construction industry. The first ready-mix factory was built during the 1930s, however the industry did not start to expand until the 1960s (Haq et al. 2013).

[8] Britannica Academia, Online ed., s.v., "Concrete." Accessed 15 January 2016. http://www.britannica.com/technology/concrete-building-material .

3.1.2 Background

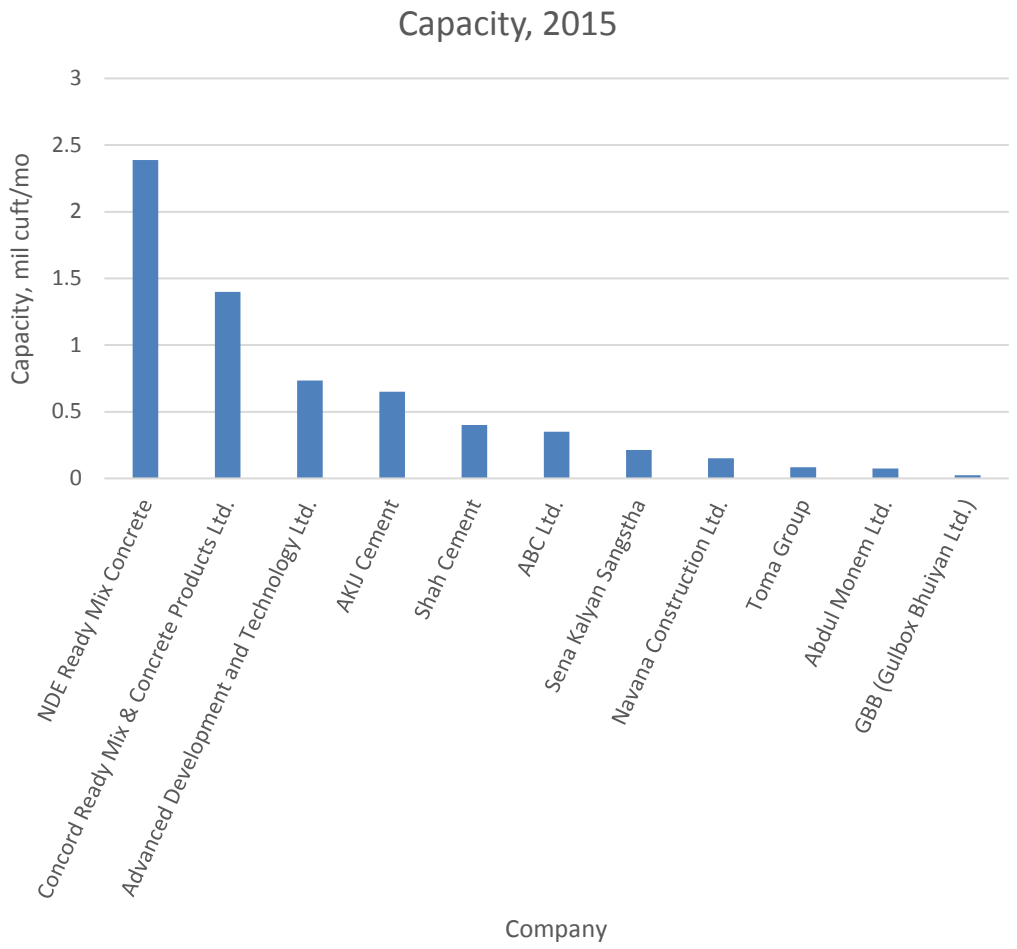
Ready-mix concrete was first established in the city of Dhaka in 1991 by Concord Ready-Mix with one batching plant, three transit mixers, and one concrete pump. Since then, the industry has evolved to a much larger scale, with many other companies emerging (Haq et al. 2013).

3.1.3 Producers

According to records for FY2010, there are around 76 ready-mix concrete plants in Bangladesh with a total capacity of around 1,200 cubic meters per hour, which creates a production of 1.8 million cubic meters of concrete per year. The industry's production is very closely related to the activity within the construction sector (Haq et al. 2013).

The top 11 companies and their installed capacities are shown in Figure 39. The figure was formed from a collection of capacities of cement companies from a variety of data sources within the material database. These data sources are included within the database itself.

Figure 39. Ready-mix concrete capacity for prominent companies in Dhaka, FY2015 (ERDC-CERL, 2016).[9]



3.1.4 Consumers

Ready Mix as a product is used typically when building activity is located in congested sites with small space available, which is why the demand for ready-mix concrete is driven by cities, such as Dhaka and Chittagong, Bangladesh. Rural locations in the country rely on concrete production on-site (Haq et al. 2013).

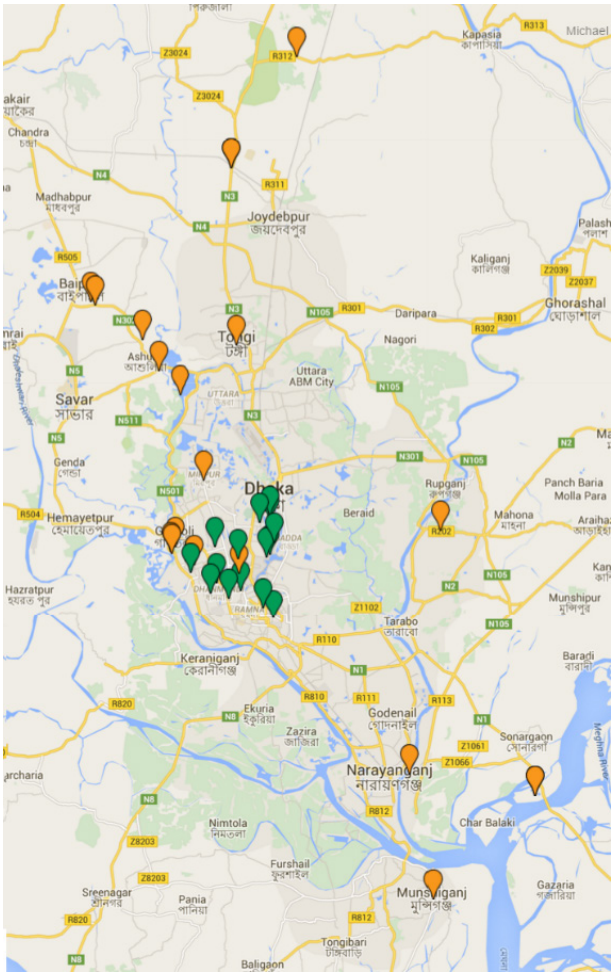
3.1.5 Locations of construction material

Ready-mix plant locations correlate with locations of cement plants in Dhaka because a portion of the companies produce both cement and concrete. Corporate offices are all located in central Dhaka, with ready-mix

[9] Capacity data is limited to companies with published production data.

plants located both along waterways and around the city. Figure 40 shows the locations of offices and plants within the Dhaka region.

Figure 40. Locations of ready-mix office and plants in Dhaka area [green: office, orange: plant] (Google Maps, 2016).



3.2 Product

3.2.1 Codes, standards, and methods

The government of Bangladesh requires concrete, constituent materials, methods, and procedures to conform to any of the standard specifications of ASTM, BS, or BDS (Technical Specifications for Buildings 2005).

Bangladesh follows the Bangladesh National Building Code (BNBC 2015), which was developed by the Local Government Engineering Department (LGED) of the Ministry of Housing and Public Projects.

According to the BNBC 2015 code, materials used in the production of concrete and admixtures for concrete shall comply with the requirements of Chapter 1 Part 2.4, which lists the standards for each of the constituents, as well as Chapter 5, which covers the mixing, production, and testing of normal weight concrete.

Concrete design is listed in Chapters 5–6 and 8–9 of the BNBC-2014 Code and describes design, rebar detailing, and prestressed concrete. Technical Specifications for Buildings (2005) provides requirements for concrete work in book Chapter 10.

3.2.2 Grade

According to Technical Specifications for Buildings (2005), Section 10.1.4, there are a number of concrete classes with different structural applications. The use of crushed stone aggregate provides a higher 28-day cylinder strength concrete compared to picked Jhama brick chips. The concrete classes are shown in Table 9.

Table 9. Concrete classes (Technical Specifications for Buildings 2005).

Concrete Class	28 day Cylinder Strength in kg/cm² (minimum)	Coarse Aggregate Type	Mix Ratio (by volume) (only indicative)
A-1	250	Crushed stone	1 : 1.5 : 3
A-2	210	Crushed stone	1 : 2 : 4
A-3	200	Picked Jhama Brick Chips	1 : 1.5 : 3
A-4	170	Picked Jhama Brick Chips	1 : 2 : 4
B-3	105	Picked Jhama Brick Chips	1 : 3 : 6

3.2.3 Reported quality

Compared to a batching plant, concrete that is mixed and prepared at a construction site has a relatively poorer quality. At the construction site, there are generally unskilled workers involved in creating concrete. When mixed on-site, water is typically added until the cement because workable, which leads to the strength lower than the target strength. This high water content creates a porous concrete which allows for harmful constituents to pass through the material and cause early deterioration. Other leading causes of deterioration in Bangladesh include unsieved and unwashed aggregates, mud in mixing water, excess aggregate, and poor mixing and proportioning of ingredients (Uddin et al. 2013).

3.3 Production factors

3.3.1 Raw materials

Bangladesh possesses a number of mineral deposits for construction aggregate; however, these sources are mostly unexploited due to the infeasibility in excavation. There are seven sand deposits, one hard rock deposit, and four gravel deposits reported by the Geographical Survey of Bangladesh.[10] Currently, only one of the deposits is being exploited and is an active mining facility in the production of granite and other construction aggregate. The active mine is the Maddhapara Granite Mining Company, located in the Rangpur Region of Bangladesh. It is owned by the company Petrobangla and has a 1.65 million MTPA capacity, with the majority of the product sold domestically (Fong-Sam 2014).

3.3.2 Imports and exports

As mentioned previously, the two main ports in Bangladesh are the Mongla Port and the Chittagong Port. Most imported materials originating from India arrive at the Mongla Port and several land ports, whereas materials imported from other countries arrive in the Chittagong Port. Most of Bangladesh's trade of cement products is with countries in Asia.

Cement is one of the most competitive industries in Bangladesh, which leads to a surplus capacity (Hossain 2015). Bangladesh exports around $12.5 million per year in cement, which is almost completely transported to India (Simoes 2013). There are only eight cement companies in Bangladesh, and they cumulatively export 0.26 million MTPA of cement via vessel to India. These companies are listed below:

- Shah Cement
- LafargeHolcim Cement
- Seven Circle Cement
- Unique Cement
- MI Cement
- Confidence Cement
- Premier Cement
- Aramit Cement

[10] Banglapedia, National Encyclopedia of Bangladesh. Online edition, s.v. "Mineral Resources." Accessed 23 June 2016. http://en.banglapedia.org/index.php?title=Mineral_Resources .

These companies all export in very low quantities and mostly to neighboring countries since they are easily accessible through water transportation (ships and mother vessels) (Nahar 2011). The country imports around $706,000 per year in cement, which originates mostly from Singapore, Egypt, Thailand, and China.

The other main component of concrete is aggregate, which is both imported and exported by Bangladesh. Coarse aggregate is exported almost exclusively to India, and fine aggregate (construction sand) is exported to China.

Coarse aggregate is imported mostly from India (71% of product). Other sources of aggregate are Asia (China, Pakistan, and Singapore) and Europe (France, Germany, Italy, and the United Kingdom).

Construction stone and hard rock is almost entirely imported because the materials are either not available or have minimal reserves in Bangladesh. Typical materials include dolomite, granite, and marble, which are imported from different parts of Asia and Europe.

Lastly, prefabricated concrete products, such as precast concrete, is exchanged mostly between Bangladesh and India. There are also some imports originating from China and Thailand (37% of product).

The total value in U.S. dollars of imports and exports of raw materials used in the production of cement is shown in Table 10.

Table 10. Imports and exports of materials for RMC, FY2013 (Simoes 2013).

Sum of Value	Material								
Country	Cement	Dolomite	Granite	Sand	Aggregate	Construction Stone	Concrete	Marble	Grand Total
Export	**$ 12,501,690**	**$ -**	**$ -**	**$ 62,100**	**$ 5,920,000**	**$ 8,390**	**$ 98,400**	**$ -**	**$ 18,590,580**
Africa									
Cote D'Ivoire	$ 1,690	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,690
Asia									
China	$ -	$ -	$ -	$ 62,100	$ -	$ -	$ -	$ -	$ 62,100
India	$ 12,500,000	$ -	$ -	$ -	$ 5,920,000	$ -	$ 98,400	$ -	$ 18,518,400
Europe									
United Kingdom	$ -	$ -	$ -	$ -	$ -	$ 8,390	$ -	$ -	$ 8,390
Import	**$ 706,620**	**$ 803,883**	**$ 2,994,784**	**$ 1,406,193**	**$ 3,869,226**	**$ 6,713,333**	**$ 4,950,735**	**$ 3,082,772**	**$ 24,527,546**
Africa									
Egypt	$ 148,200	$ -	$ -	$ 225,600	$ -	$ 3,941	$ -	$ 147,840	$ 525,581
Madagascar	$ -	$ -	$ 5,083	$ -	$ -	$ -	$ -	$ -	$ 5,083
Asia									
China	$ 115,000	$ -	$ -	$ -	$ 251,550	$ 5,392,096	$ 1,740,700	$ -	$ 7,499,346
India	$ 21,440	$ 794,970	$ 2,631,200	$ 211,500	$ 2,747,700	$ 1,068,800	$ 3,106,445	$ 338,800	$ 10,920,855
Malaysia	$ 4,980	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,980
Pakistan	$ -	$ 3,051	$ -	$ -	$ 356,040	$ 59,452	$ -	$ 203,280	$ 621,823
Singapore	$ 275,000	$ -	$ -	$ 831,900	$ 81,270	$ -	$ 2,460	$ -	$ 1,190,630
South Korea	$ -	$ -	$ -	$ 49,350	$ -	$ -	$ -	$ -	$ 49,350
Thailand	$ 142,000	$ 5,862	$ -	$ 5,781	$ -	$ 12,692	$ 99,365	$ -	$ 265,700
Europe									
France	$ -	$ -	$ -	$ 18,330	$ 116,100	$ -	$ -	$ -	$ 134,430
Germany	$ -	$ -	$ -	$ 11,562	$ 108,360	$ -	$ -	$ -	$ 119,922
Greece	$ -	$ -	$ -	$ -	$ -	$ 29,392	$ -	$ 126,280	$ 155,672
Italy	$ -	$ -	$ 218,270	$ -	$ 181,890	$ 133,600	$ -	$ 283,360	$ 817,120
Norway	$ -	$ -	$ 17,641	$ -	$ -	$ -	$ -	$ -	$ 17,641
Portugal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,012	$ 12,012
Spain	$ -	$ -	$ 8,671	$ -	$ -	$ -	$ -	$ -	$ 8,671
Turkey	$ -	$ -	$ 92,690	$ -	$ -	$ -	$ 1,765	$ 1,971,200	$ 2,065,655
Ukraine	$ -	$ -	$ 21,229	$ -	$ -	$ -	$ -	$ -	$ 21,229
United Kingdom	$ -	$ -	$ -	$ 21,150	$ 26,316	$ -	$ -	$ -	$ 47,466
North America									
United States	$ -	$ -	$ -	$ 31,020	$ -	$ 13,360	$ -	$ -	$ 44,380

3.3.3 Technology

The basic process in creating ready-mix concrete has been unchanged since the mid-20th century, as described in the steps below.

1. The dry cement mix, aggregates, and admixtures are measured into a bin in a stage called batching, according to a set of instructions for a final product. This process is completed through an electronic system, which is controlled by an operator to handle weighing and mixing. This technology was introduced during the late 1970s and early 1980s.
2. The mix is then placed onto a truck, where water is added. These two steps are interchangeable and depend on the practice of the plant. The typical capacity for current cement trucks is 10 cubic yards to as much as 12 cubic yards and results in a truck that weighs as much as 38 tons after loading.

3. Once at the construction site, concrete pumps are used by construction contractors or firms to place the concrete on a job site (Syverson 2008).

3.3.4 Transportation and distribution

One of the disadvantages of concrete is that it must be placed within around 120 minutes after batching at the plant, which is a very limited time span. Delivery of concrete from the batch plant to the construction site is a logistical coordination since the product is perishable and time-sensitive to buyers. Deliveries are typically coordinated through a central office when a company possesses multiple batch plants. There is typically an optimization of delivery flexibility, capacity, and backup capability based on the location of plants (Syverson 2008).

3.3.5 Power

The power consumption for a ready-mix plant varies based on its size, which results in a range between 100 kW and 500 kW (Jahid 2016).

4 Aggregates

Aggregates are characterized as stones, gravel, and sand and are designated by their grade, which is a spectrum from fine-to-coarse material ranging from 0.001-1.5 in.[11]

4.1 Industry

4.1.1 Background - Jhama brick chips

Brick chips have been used in Bangladesh to produce concrete for years, due to the lack of stone availability. There are an estimated 5,000 brick kilns operating in Bangladesh, with 1,000 brick kilns surrounding Dhaka. The largest proportion of bricks are Bangla bricks which are molded by hand and fired in traditional kilns. The heavily fired bricks are broken up into pieces referred to as pickets, which make up 15%–20% of the production of a fixed chimney kiln and are a substitute for stones which are generally unavailable in Bangladesh. The pickets are mixed with cement to form concrete used in building construction, and they are used for other tasks such as building paved roads (Luby et al. 2015). Compared to production of stone product, there is greater damage to agricultural land and deforestation due to the use of firewood (Wee and Lee 1996).

4.1.2 Background - crushed stone

Bangladesh is almost entirely dependent on imported stone, with a demand of 7 million metric tons in FY2013 (Uddin et al. 2013). Crushed stone is an expensive material in Bangladesh, which is why there is a greater presence of bricks in aggregate (Hossain et al. 2011).

4.1.3 Background - gravel

The total gravel reserves is around 10 million cubic meters and it is a resource currently being exploited and used in Bangladesh. Gravel deposits are available along the foothill areas of the Himalayas. The deposits are typically river-borne and travel downstream during the rainy season.[12]

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[11] Britannica Academia, Online ed., s.v., "Concrete." Accessed 15 January 2016. http://www.britannica.com/technology/concrete-building-material.

[12] Banglapedia, National Encyclopedia of Bangladesh. Online edition, s.v. "Mineral Resources." Accessed 07 January 2016. http://en.banglapedia.org/index.php?title=Mineral_Resources.

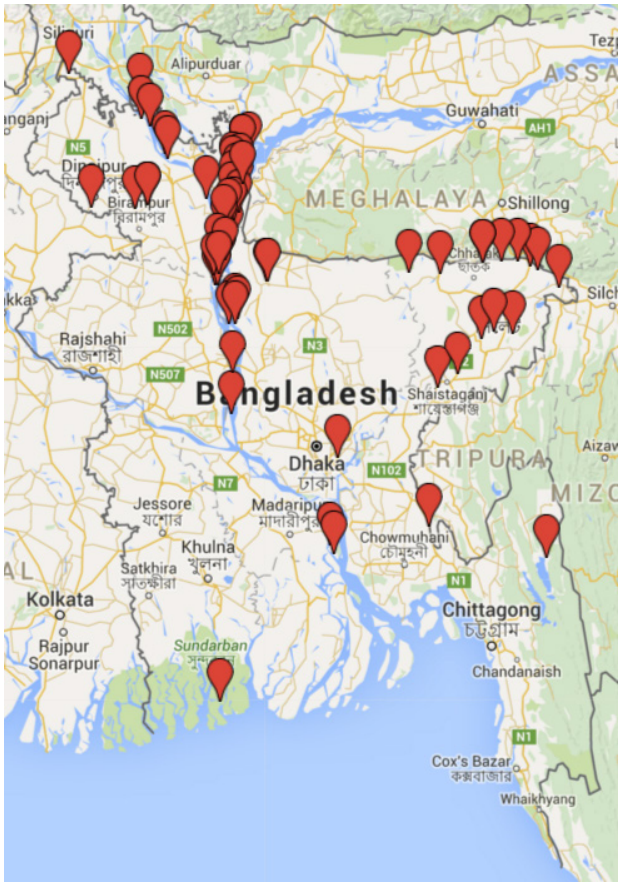
4.1.4 Background - construction sand

Construction sand is a plentiful resource in Bangladesh and is available in riverbeds throughout the country. Sand is composed of quartz of medium and coarse grain (“Mineral Resources” 2014).

4.1.5 Location of construction material

The geography of Bangladesh determines where aggregates are located throughout the country. Sand and gravel are located mostly along the Jamuna (Brahmaputra) River and the Teesta River in the north and the Meghna river in the south. Stone and gravel are located mostly in the Sylhet region along the border of India and Bangladesh due to the mountainous geography of the area. Stone can also be found in the Chittagong region in the mountains of the Chittagong Hill Tract. Sand is located in the Sylhet region as well along the lesser rivers running from India into Bangladesh. Locations of aggregates within Bangladesh can be found in Figure 41.

Figure 41. Locations of aggregates in Bangladesh [red: deposit] (Google Maps, 2016).



4.1.6 Locations of aggregates in India

Within northeast India, gravel and sand are located along the Brahamputra River, which stretches from the northeast border between the Indian states of Arunachal Pradesh and Nagaland to the north border between Bangladesh and India. There are additional sand and stone quarry sites along the north Bangladesh-India border. Locations of aggregates in northeast India can be found in Figure 42.

Within east India, sand and gravel are located along the rivers, including the Mahanadi, Hooghly, Hasdo, Damodar, Subarnarekha, and Baitarani Rivers. There is a spread of stone quarries throughout the region as well. Locations of aggregates in east India can be found in Figure 43.

Figure 42. Locations of aggregates in northeast India [red: deposit] (Google Maps, 2016).

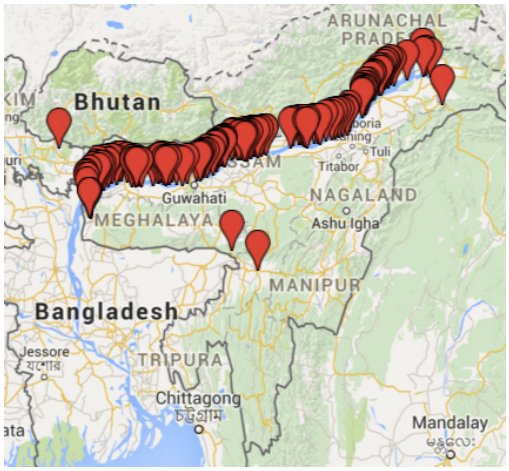
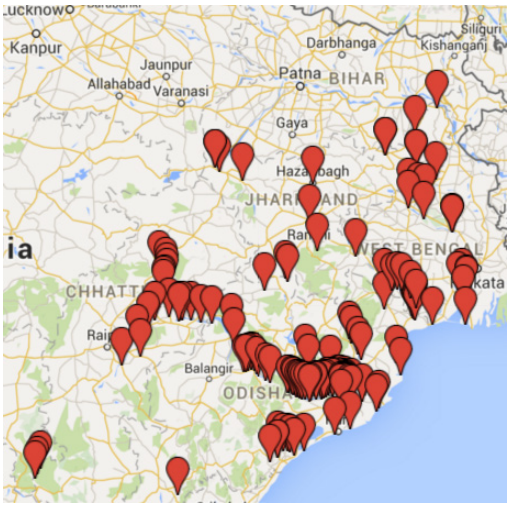


Figure 43. Locations of aggregates in east India [red: deposit] (Google Maps, 2016).



4.2 Product

4.2.1 Codes, standards, and methods

Concrete aggregates shall conform to the standards "Coarse and Fine Aggregates from Natural Sources for Concrete" (BDS 243: 1963) and "Specification for Concrete Aggregates" (ASTM C33/C33M-08).

4.2.2 Construction material - Jhama brick chips

The absorption and abrasion of brick aggregates and brick chips is higher than stone aggregates and shingles. Brick chips have the lowest workability because of the internal friction between the aggregates and because of the higher absorption. More water is typically added to mixes with brick chips to improve the workability (Uddin et al. 2013).

4.2.3 Construction material - crushed stone

The quality of stone chips may be questionable. Shingles, or round-shaped stone, are used in construction because they provide better workability due to their round shape (Uddin et al. 2013).

4.2.4 Construction material - demolished concrete

Recycled concrete brick is another possibility for use as an aggregate. Through recycling, it is possible to create a concrete with a higher strength compared to the strength of in-situ concrete of old structures in Bangladesh. The material is a coarse aggregate which produces a concrete strength of around 20.7–31.0 MPa. The compressive strength is similar to that of a virgin-class brick aggregate concrete for up to 50% replacement of brick. The performance was found to be better for a water content of 0.45 (Mohammed et al. 2014).

5 Timber

5.1 Background

Wood has been put to use since humans appeared on Earth. The natural material is a strengthening tissue of trees and other plants, and it is plentiful and has multipurpose uses. There are an estimated 3,000–4,000 species of plants that produce wood that is suitable for material use. It has large economic importance because it can be found throughout the world and is a renewable resource. Wood is strong in relation to its weight and has insulating capacity to heat and electricity. It is the raw material for lumber, furniture, plywood, wood-based panels, fuel, pulp and paper, and a number of chemical products.

5.1.1 Types of products

There are a number of products derived from manufacturing of wood which possess varying structural properties and processing techniques.

5.1.1.1 Natural wood

Round wood products are used to make poles, posts, and certain mine timbers and are typically given a preservative treatment. Sawn wood is referring to products derived from a sawmill. The main product of sawn wood is lumber, which is used in logs, timber, or members of light-frame construction. Timber is used for heavy construction and can be classified as hardwood or softwood.

5.1.1.2 Layered wood

Veneer is another common product, which is a thin sheet of wood of uniform thickness (around 0.02–0.04 in.), and it is used for plywood, furniture, and other household products. Plywood is composed of layers of glued veneer, with different grains crossing each other at right angles. The material allows for: stability across more dimensions than natural wood, uniform strength, splitting resistance, panel forming, and more decorative value. Structurally it is used for walls, floors, roofs, doors, and has many other applications. Similarly, laminated wood is built with glued layers of wood; however, the grain of the wood pieces are glued parallel to the member's length. Laminated wood is used for load-carrying members such as beams or arches.

5.1.1.3 Wood residue and fibers

Particle board is a product manufactured with flake-like forms of wood glued together, typically from sawmill and other wood industry residues. The product is used for interior uses such as furniture, paneling and doors, as well as for structural purposes. Fiberboard is made from wood fibers which are held together by physical forces (hydrogen bonding), flowing of lignin in fibers, or interweaving of fibers. There are two types of fiberboard: insulation and compressed. Insulation board is used in construction for insulation and cushioning, whereas compressed wood has a variety of uses such as furniture, wall paneling, house siding, and concrete forms. A relatively new compressed product is medium density fiberboard (MDF), which is used for the same applications as compressed wood.[13]

5.1.1.4 Bamboo

Bamboo is a subfamily of tall tree-like grasses with over 1,400 species and is located in tropical, subtropical, and mild temperate regions. It is a fast-growing plant which grows in clusters and consists of woody, ringed stems called culms, which are typically hollow. Bamboo has a wide range of uses, especially for those in East and Southeast Asia. Some of the structural purposes of bamboo culms include planks for houses and rafts, scaffoldings, and flooring.[14]

5.2 Industry

5.2.1 Global scenario

Unlike mineral-based industries, global forest resources are renewable and can be maintained indefinitely through proper management. The act of deforestation of tropical areas accounts for 20% of total human caused carbon dioxide emissions. This demand for preservation has led to the formation of forest certification programs. Through certification, forest managers and owners are given recognition for forest management practices, which protects the environment and is a sustainable solution. Within Europe and North American, roughly 50% and 35% of forests are certified,

[13] Britannica Academia, Online ed., s.v., "Wood." Accessed 15 January 2016. http://www.britannica.com/science/wood-plant-tissue.

[14] Britannica Academia, Online ed., s.v., "Bamboo." Accessed 15 January 2016. http://www.britannica.com/plant/bamboo.

respectively. Whereas in Africa and Asia, this number is approximately 1.0% (Fernholz and Kraxner 2012).

Bangladesh has the fourth-strongest annual growth forecast for wood-based panels at 4.3% annually, and is ranked 10th for market potential, which indicates that the market will have more potential in the coming years. Globally, the growth for the industry is forecasted to be 2.2% per annum for 2015–2019. Plywood has the largest global demand at 43.1%, followed by fiberboard (24.1%), veneered panels (13.3%), particle board (7.9%), veneers and plywood sheets (7.3%), waferboard (4.0%), and densified wood (0.4%) ("Wood-Based Panel Markets" 2015).

5.2.2 Background

5.2.2.1 Forest resources

Currently, timber is expensive in Bangladesh due to deforestation. Two-thirds of timber is used for fuel in cooking and industry, the rest is used for paper and construction. In 1989, the Bangladeshi government imposed a moratorium on log cutting from any natural forest, and therefore the country's domestic use of timber is limited to plantations (Choudhury 2016).

Historically, bamboo has been the most widely used building material within Bangladesh, specifically in construction of homes because 60%–70% of homes are built with bamboo (Tariq and Jinia 2012). However, bamboo has a similar future as timber: with population growth in Bangladesh, plantation land for bamboo is being destroyed or converted to other crops. The cost of growing bamboo has been increasing over the past decade, which has caused many bamboo plantation owners to either change professions or become unemployed ("Homestead Bambo" 2015).

Flooding has a large effect on the production of timber and bamboo. Trees aged 1–32 years typically have been found to be affected. Long periods of inundation and waterlogging cause root rotting, permanent wilting, defoliation of trees, and absence of air in root system which affects respiration. There are two types of wilting that occur: physiological due to water stress and water logging, and pathogenic due to infection by fungus (Basak et al. 2015).

5.2.2.2 Production

Bangladesh has a long history of plantation forestry, beginning in 1871 with teak, which was the dominant plantation species until the 1960s. It was found that teak removes soil fertility, prevents undergrowth vegetation, and has success only in suitable site conditions. Therefore, more than 130 different exotic tree species have been tried in plantation programs; however, only a select number have shown promising growth performance.[15] It has been reported that 20%–30% of all plantations established during the last 30 years have been destroyed, and those surviving have reduced capacity from lack of proper maintenance. Many plantations have been converted into rice fields because of the growing population in Bangladesh, which has been increasing the demand for the product. However, the plantation program has been increasing in size daily, with exotic species having preference over indigenous species (Hossain 2003).

The sawmilling sector within Bangladesh contributes about 2% to the gross national product (GNP). There is a rapid increase in the number of operating sawmills, which indicates that it is profitable.

5.2.3 Producers

5.2.3.1 Forest resources

There are two government agencies responsible for Bangladesh timber and bamboo resources. The Bangladesh Forest Department (BFD) is responsible for managing and establishing plantations, harvesting, selling forest produce, and developing parks and gardens. The Bangladesh Forest Research Institute (BFRI) and Bangladesh Forest Industries Development Corporation (BFIDC) conduct research and process timber and forest products (Basak et al. 2015).

Bangladesh has very limited forest resources, with uneven distribution of forest across the country. Natural forest density is getting thinner over

[15] These exotic tree species are are *Tectona grandis, Paraserianthes falcataria, Hevea brasiliensis, Dalbergia sissoo, Swietenia macrophylla, Acacia nilotica, Eucalyptus camaldulensis, E. tereticornis, Pinus caribaea, Xylia kerrii, Leucaena leucocephala, Acacia mangium, A. auriculiformis* and *Gliricidia sepium*. However, *Eucalyptus camaldulensis, Acacia mangium* and *A. auriculiformis* have already been removed from large-scale plantation programs because of the controversy about their suitability or poor effects on the ecosystem.

time. The yearly production of wood logs is estimated to be 1.8 cubic meters for FY2015. Village forests supply 55%–85% of all wood consumed (Rahman 2012).

In total, village forests account for 1 million cubic meters is logs, 4 million cubic meters in fuel wood, and 0.53 million metric ton (MT) of bamboo in one year (Govil 2000). Rural sawmilling depends on village forest resources, while urban sawmills rely on timber resources from village and government forests. The southern and southeastern regions have the best stock of private wood supplies at medium supply. At the same time, the northwest and northeast regions have lower stock of private tree resources (Govil 2000).

The level of production of bamboo is declining, despite its high demand and profit (Stulz 1992). There are a lack of well-managed bamboo plantations and forests, so prices have been increasing. Farmers in the northwest, northeast, and west hold 70% of private bamboo resources, at 13 culms per capita (Govil 2000).

5.2.3.2 Production

Sawmills in Bangladesh are mostly private, widely distributed, and make up a small footprint in area. There are officially 4,500 sawmills in the country without pitsaws and 10,000 units with pitsaws. Sawmills are either of regional manufacture (India and Pakistan) or more recently of local manufacture (Islam et al. 2013). For timber production, the daily capacity of each sawmill is around 2 cubic meters, which is a capacity of 2.7 million cubic meter in a year. For plywood, most of the units are old and have an annual capacity of around 4 mil. square meters. The production locally appears much greater than local commercial plywood demand. (Govil 2000).

The sawmill sector in Bangladesh can be classified as old, inefficient, and underutilized. Sawmills have low productivity, inefficient management, and high waste. Sawmills have been operating around 63% of the present capacity, which shows that there is a lower scale of production. The managerial capability and technical knowledge does not contribute to a high standard return on its investment. Waste occurs in the form of work-time because of log shortage and lack of maintenance. The facilities compete against other processing facilities to reduce the number of logs in the forest. There is a clear need for improvement within the sector to minimize waste of usage timber (Islam et al. 2013).

5.2.4 Consumers

Production of timber cannot keep pace with the demand. The gap between timber demand and production is continuing to grow larger over time. The highest demand is from Dhaka and the central part of country; however, this area has the fewest timber resources. The per capita consumption is 0.005 cubic meters, which is the lowest compared to surrounding countries. The 2015 demand is estimated to be 6.8 million cubic meters (Rahman 2012).

5.2.5 Locations of construction material in Bangladesh

Locations of timber in Bangladesh can be found in Figure 44. Forested areas in Bangladesh are mostly along the borders of the country, which include the Chittagong Hill Tracts, Sylhet, the Sundarbans in southwest Bangladesh, and in the Rangpur Region. There are also a few forests located in North Central Dhaka.

Saw mills are mostly located along highways and major roads within the country and tend to avoid locations along rivers, most likely due to the ability to transport raw materials and finished product on land. The largest clusters of saw mills are in major cities such as Dhaka, Jessore, Khulna, Barisal, and Chittagong. These areas are shown in Figure 45, Figure 46, and Figure 47. These clustered locations are due to urbanization and thus the larger demand for timber in these areas.

A larger range of products are generally produced within the city of Dhaka, such as veneer board, particle board, and plywood. Whereas in other, lesser regions such as Khulna, Rajshahi, and Rangpur, there are generally particle board mills. Chittagong supplies mostly plywood product.

Figure 44. Locations of timber in Bangladesh [red: plant, green: deposit, blue: office] (Google Maps, 2016).

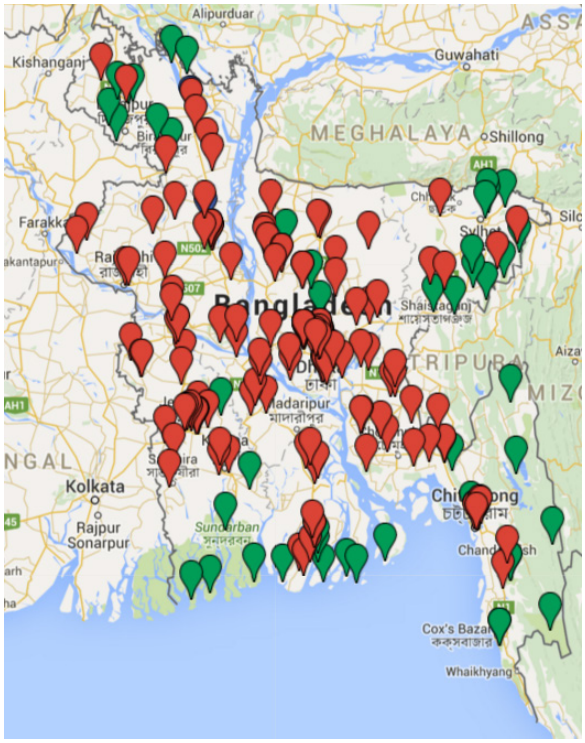


Figure 45. Locations of timber in Dhaka, Bangladesh [red: plant, blue: office] (Google Maps, 2016).

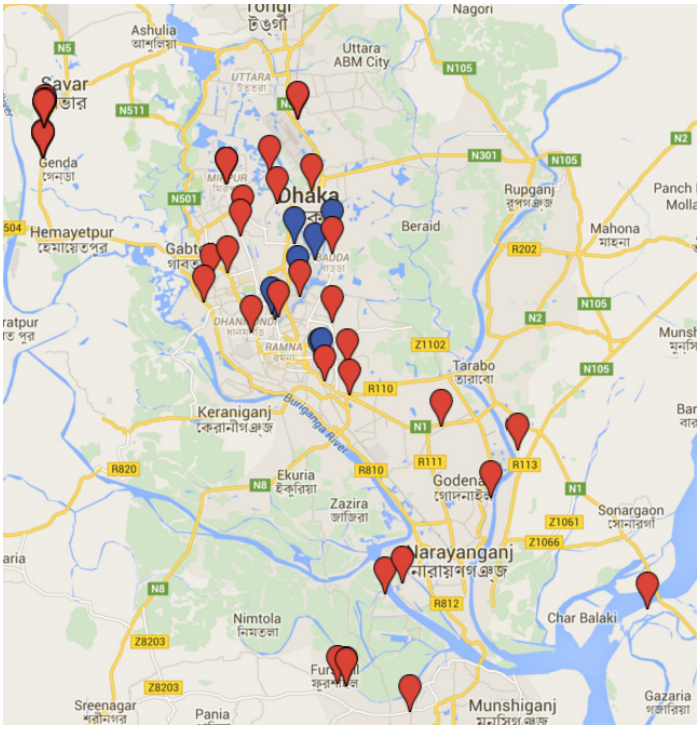


Figure 46. Locations of timber in Jessore and Khulna, Bangladesh [red: plant, green: deposit] (Google Maps, 2016).

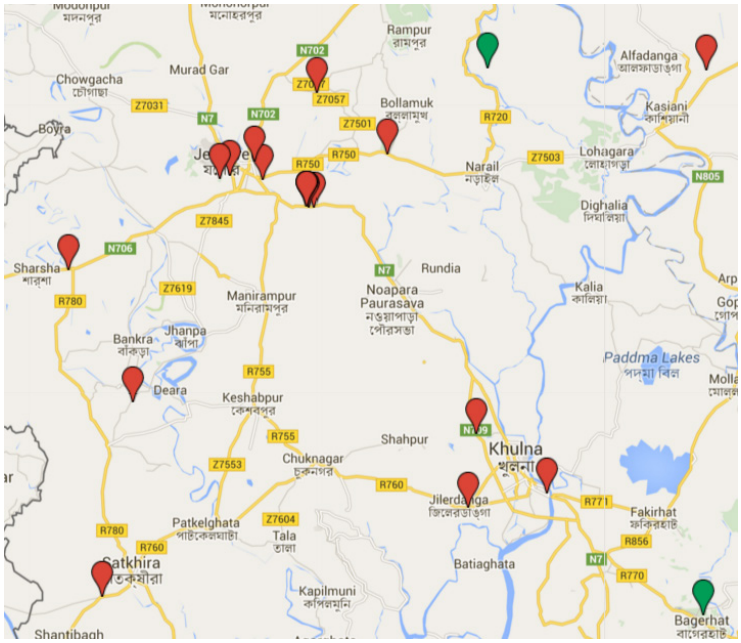
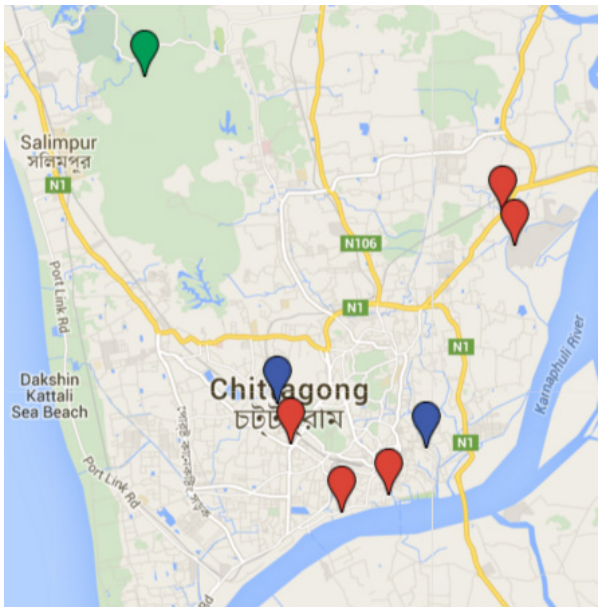


Figure 47. Locations of timber in Chittagong, Bangladesh [red: plant, green: deposit, blue: office] (Google Maps, 2016).



5.2.6 Construction material industry in India

India's imports of timber and timber products has increased significantly over the past decade, from $500 million to $2.7 billion, due to restrictions on domestic harvesting and limited forest resources. India is a large wooden

furniture exporter. For Bangladesh, India is the largest source of imported wood veneer.

The forest cover of India is around 22% of the land cover, with a significant portion of forest in mountainous regions that are difficult to access. The eight northeast states are the most densely forested areas of India and represent a quarter of the forest cover. Two policies have had a significant effect on the industry. The 1988 National Forest Policy called for a substitution of wood wherever possible, which slowed timber production and sparked the sustainable importation of logs. Additionally, the 1997 Supreme Court of India ruled that only central government could approve forestry land for any non-forestry purposes, which closed saw mills lacking approval to harvest and lowered domestic production, especially in northeast India.

5.2.7 Construction material industry in Malaysia

Malaysia has the world's largest area of certified tropical forest, with a total of 5.79 million hectares. As a result, there is a large demand for certified timber products globally from Malaysia. Malaysia is among the largest exporters of wood products in the world. The largest sectors of these exports include sawn timber, plywood, and wooden furniture. For Bangladesh, Malaysia provides the largest source of particle board.

There are a number of policies which have stimulated the timber industry in Malaysia. The Promotion of Investment Act of 1986 relieves income tax from industrial, agricultural and other commercial enterprises, which promotes exports from the wood-based industry. The National Timber Industry Policy (NATIP 2009–2020) was established to help the timber industry become dynamic and progressive with better quality timber products through the year 2020 (Harun et al. 2014).

5.3 Product

5.3.1 Codes, standards, and methods

Timber construction is described in Part 6, Chapter 11 of the Bangladesh National Building Code (BNBC-2014). Material standards for timber and wood products and their relevant codes are listed in Part 5, Chapters 2.8 and 2.9.

5.3.2 Construction material - timber

Teak is often seen as a benchmark with respect to grade and prices of other wood species because of its availability and resistance to termites and decay. The major species in plantations include the *Acacia nilotica, Dalbergia sissoo, Tectona grandis, Lagerstroemia spp., Gmelina arborea, Sonneralia apetale*. All other species are classified as least concern, are data deficient, or have not been evaluated according to International Union for Conservation of Nature (IUCN) Red List of Endangered Species (IUCN Red List 2016).

Of this sample of timber for construction, the major forest species within Bangladesh include the *Dipterocarpus alatus, Heritiera spp., Hopea odorata, Michelina montana*, and *Syzygium spp*. Within the Hill Forests of Bangladesh, one can find *Artocarpus chaplasha, Dipterocarpus alatus, Duabanga sonneratioides, Pterygota alata*, and *Swintonia floribunda*. In Littoral Mangrove Forest areas are typically the *Bruguiera conjugata, Ceriops roxburghiana, Heritiera spp., Sonneralia apetale*, and *Xylocarpus rolloensis* species. Within Plain Sal Forest are the *Shorea robusta* and *Lagerstroemia spp*. (Govil 2000). From this list, *Hopea odorata* is classified as vulnerable and *Ceriops roxburghiana* is near threatened. All others are classified as least concern, are data deficient, or have not been evaluated according to IUCN Red List of Endangered Species (IUCN Red List 2016).

The species of timber as provided in Table 11.4.1 of the BNBC-2014 code are presented in Table 11, Table 12, Table 13, and Table 14, along with Figure 48.

Table 11. Safe permissible stresses for the species of timber (BNBC 2014, Table 11.4.1).

Table 11.4.1 Safe Permissible Stresses for the Species of Timber

Species		Average Density at 12 percent Content Kg/m^3	Modulus of Elasticity x 10^3 N/mm^2	Permissible Stress in N/mm^2 for Grade I											Preservative Characters		
Botanical Name	Trade Name			Bending and Tension Along Grains, Extreme Fibre Stress			Shear all Location		Compression Parallel to Grain			Compression Perpendicular to Grain			Durability Class	Treatability Grade	Refracterines to All Seasoning
				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Acacia nilotica	Babla	797	_	_	12.9	10.3	1.4	2.1	8.9	7.9	6.4	5.2	4.0	3.3	I	b	B
Aglaia odulis	Aglaia	815	12.56	18.2	15.2	12.1	1.4	2.0	10.1	8.9	7.3	4.4	3.4	2.8	_	_	A
Ailantahus grandis	Gokul	404	7.94	8.3	6.9	5.5	0.6	0.8	5.3	4.7	3.9	1.1	0.9	0.7	III	_	C
Altingia excelsa	Jutili	795	11.37	17.1	14.3	11.4	1.2	1.8	11.0	9.8	8.0	6.8	5.3	4.4	II	e	A
Amoora rehituka	Pitraj	668	8.98	12.3	10.2	8.2	1.1	1.5	8.0	7.1	5.8	4.0	3.1	2.6	I	_	B
Amoora wallichii	Lali	583	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Amoora spp.	Amari	625	1.05	13.4	1.1	9.2	0.9	1.3	8.4	7.4	6.0	3.7	2.9	2.4	II	d	B
Anisoplera glabra	Boilam	573	_	_	_	_	_	_	_	_	_	_	_	_	III	b	_
Aphenamixis polystachya	Pitraj	583	_	_	_	_	_	_	_	_	_	_	_	_	III	e	B
Arlocarpus chaplasha	Chapalish	515	9.11	13.2	11.0	8.8	0.9	1.2	8.5	7.5	6.2	3.6	2.8	2.3	III	d	B
Artocarpus integrifolia	Kanthal	537	_	_	_	_	_	_	_	_	_	_	_	_	III	c	B
Azadirachta indica	Neem	836	8.52	14.6	12.1	9.7	1.3	1.8	10.0	8.9	7.3	5.0	3.9	3.2	_	_	_
Betula lnoides	Birch	625	9.23	9.6	8.0	6.4	0.8	1.1	5.7	5.0	4.1	2.2	1.7	1.4	_	_	B
Bischofia javanica	Bhadi	769	8.84	9.6	8.2	6.5	0.8	1.1	5.9	5.3	4.3	3.6	2.8	2.3	III	_	A
Bruguiera conjugata	Kankra	879	_	_	_	_	_	_	_	_	_	_	_	_	_	_	A

Table 12. Safe permissible stresses for the species of timber, continued (BNBC 2014, Table 11.4.1).

Species		Average Density at 12 percent Content Kg/m³	Modulus of Elasticity x 10^3 N/mm²	Permissible Stress in N/mm² for Grade I											Preservative Characters		
Botanical Name	Trade Name			Bending and Tension Along Grains, Extreme Fibre Stress			Shear all Location		Compression Parallel to Grain			Compression Perpendicular to Grain			Durability Class	Treatability Grade	Refracterines to All Seasoning
				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Bucklandia populnea	Plpli	672	9.89	12.8	10.7	8.6	1.1	1.5	7.9	7.0	5.7	3.5	2.7	2.2	III	e	C
Canarium strictum	White dhup	569	10.54	10.1	8.4	6.7	0.7	1.1	6.2	5.5	4.5	2.1	1.6	1.3	III	–	C
Cassia fistula	Sonalu	865	11.80	19.2	16.0	12.8	1.4	2.0	12.3	10.9	8.9	7.2	5.6	4.6	I	–	A
Castanopsis hystrix	Chestanut	624	9.85	10.6	8.8	7.0	0.8	1.2	6.4	5.7	4.6	2.7	2.1	1.7	II	b	B
Carallia lucida	Maniawaga	748	12.60	18.4	15.3	12.3	1.2	1.7	11.4	10.1	8.3	5.9	4.6	3.8	–	–	–
Cassia siamea	Minjiri	695	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chukrasia tabularis	Chickrassy	666	8.35	11.8	9.8	7.9	1.1	1.5	7.1	6.3	5.2	3.9	3.1	2.5	II	c	B
Dalbergia sissoo	Sissoo	808	–	–	–	–	–	–	–	–	–	–	–	–	–	–	B
Dillemia indica	Dillenia	617	8.61	12.1	10.0	8.0	0.8	1.2	7.3	6.5	5.3	2.7	2.1	1.7	III	a	B
Dillenia pentagyne	Dillenia	622	7.56	11.8	9.9	7.9	0.9	1.3	7.1	6.3	5.2	3.5	2.7	2.2	III	d	B
Dipterocarpus alatus	Garjan	721	–	–	–	–	–	–	–	–	–	–	–	–	III	a	B
Dipterocarpus macrocarpus	Hollong	726	13.34	14.5	12.0	9.6	0.8	1.1	8.8	7.9	6.4	3.5	2.7	2.2	III	a	B
Duabanga sonneratioides	Banderhol	485	8.38	9.8	8.2	6.5	0.6	0.9	6.4	5.7	4.7	1.8	1.4	1.1	III	c	C
Garuga piannata	Garuga	571	7.58	11.7	9.7	7.8	1.0	1.5	7.2	6.4	5.3	3.4	2.6	2.1	I	e	B
Geriops roxbarghiana	Goran	869	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
gGmeline arborea	Garnar	501	7.02	9.8	8.2	6.6	0.8	1.4	5.7	5.0	4.1	4.2	3.2	2.7	I	e	B
Grewia veslita	Dhaman	758	12.00	15.4	12.6	10.3	1.4	2.0	9.1	8.1	6.6	4.1	3.2	2.6	III	d	B
Heritiera spp.	Sundri	872	13.37	17.9	14.9	11.9	1.3	1.8	11.0	9.8	8.0	6.5	5.0	4.1	I	–	A

Table 13. Safe permissible stresses for the species of timber, continued (BNBC 2014, Table 11.4.1).

Species		Average	Modulus of	Permissible Stress in N/mm² for Grade I											Preservative Characters		
Botanical Name	Trade Name	Density at 12 percent Content Kg/m³	Elasticity x 10³ N/mm²	Bending and Tension Along Grains, Extreme Fibre Stress			Shear all Location		Compression Parallel to Grain			Compression Perpendicular to Grain			Durability Class	Treatability Grade	Refracterines to All Seasoning
				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hopea odorata	Telsur	711	–	–	–	–	–	–	–	–	–	–	–	–	III	a	B
Kayea floribund	Karal	813	10.88	16.8	14.0	1.1	1.1	1.6	10.1	9.0	7.3	4.4	3.4	2.8	III	–	–
Lagerstrocmia spp.	Jarul	654	–	–	–	–	–	–	–	–	–	–	–	–	III	e	B
Machilus macrantha	Machilus	692	10.00	12.4	10.3	8.3	1.0	1.5	8.2	7.3	6.0	3.5	2.7	2.2	III	e	B/C
Manglietia insignia		449	10.37	10.9	9.1	7.3	0.7	1.4	8.0	7.1	5.8	3.4	2.6	2.1	–	–	–
Manilota polyandra	Ping	903	13.20	19.1	15.9	12.7	1.3	1.8	1.2	10.0	8.5	5.7	4.4	3.6	III	b	A
Mesua assamica	Keyea	842	12.83	17.4	14.5	11.6	1.0	1.4	11.7	10.4	8.5	5.3	4.1	3.3	II	e	–
Mesua ferrea	Mesua	965	16.30	23.3	19.4	15.5	1.2	1.8	15.5	13.8	11.3	5.9	4.6	3.7	I	–	A
Michelia champaca	Champa	644	–	–	–	–	–	–	–	–	–	–	–	–	–	–	B
Michelia montana	Champ	512	8.25	10.9	9.1	7.3	0.7	1.0	6.6	5.9	4.8	2.8	2.2	1.8	I	–	B
Michelia excelsa	Champ	513	10.12	9.8	8.2	6.5	0.7	1.0	6.1	5.5	4.5	1.6	1.3	1.0	II	e	B
Mitragyna pervifolia	Dakroom	651	7.82	12.6	10.5	8.4	1.0	1.5	7.9	7.0	5.7	3.7	2.9	2.4	III	b	B
Palaquium polyanthum	Tali	734	11.24	14.9	12.4	10.0	1.1	1.6	9.9	8.8	7.2	4.7	3.7	3.0	–	–	B
Phoebe hainesiana	Bonsum	566	9.5	13.2	11.0	8.8	0.8	1.2	8.8	7.8	6.4	2.8	2.1	1.8	II	c	B
Phoebe goalperansis	Bonsum	511	7.65	9.7	8.1	6.5	0.7	1.0	6.6	5.9	4.8	2.2	1.7	1.4	II	c	B
Plerygota alata	Narikel	593	10.95	13.4	11.8	8.9	0.8	1.2	8.2	7.3	6.0	2.7	2.1	1.7	III	–	C
Prunus napeulensis	Arupati	548	9.41	4.4	8.7	69.6	0.9	1.2	6.7	6.0	4.9	2.4	1.9	1.6	–	–	–
Pterospermum acerifolium	Hattipaila	607	9.55	13.5	11.3	9.0	0.9	1.2	8.7	7.7	6.3	3.2	2.5	2.0	III	c	B

Table 14. Safe permissible stresses for the species of timber, continued (BNBC 2014, Table 11.4.1).

Species		Average	Modulus of	Permissible Stress in N/mm² for Grade I											Preservative Characters		
Botanical Name	Trade Name	Density at 12 percent Content Kg/m³	Elasticity x 10³ N/mm²	Bending and Tension Along Grains, Extreme Fibre Stress			Shear all Location		Compression Parallel to Grain			Compression Perpendicular to Grain			Durability Class	Treatability Grade	Refracterines to All Seasoning
				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Quercus lineate	Oak	874	12.63	15.2	12.7	10.1	1.2	1.7	9.6	8.6	7.0	5.3	4.1	3.4	II	c	A
Quercus lamellosa	Oak	87	12.44	14.5	12.1	9.7	1.2	1.7	8.7	7.8	6.4	3.8	2.9	2.4	II	c	A
Schima wallichii	Chilauni	693	9.57	11.1	9.3	7.4	0.9	1.3	6.6	5.9	4.8	2.3	1.8	1.4	III	d	B
Seritiera fomes	Sundri	1073	–	–	–	–	–	–	–	–	–	–	–	–	III	b	B
Shotea assamica	Makai	548	9.27	11.1	9.2	7.4	0.9	1.3	7.1	6.3	5.2	2.9	2.2	1.8	III	c	B
Shorea robusta	Sal	889	–	–	–	–	–	–	–	–	–	–	–	–	III	e	B
Sonneralia apetale	Keora	617	8.63	12.8	10.7	8.5	0.9	1.3	7.4	6.6	5.4	4.8	3.7	3.0	II	–	B
Swintonia floribunda	Civit	665	–	–	–	–	–	–	–	–	–	–	–	–	III	a	C
Syzygium cumini	Jamun	841	10.55	14.8	12.4	9.9	1.1	1.6	9.0	8.0	6.5	6.9	5.4	4.4	II	e	A
Syzygium spp.	Jam	823	–	–	–	–	–	–	–	–	–	–	–	–	III	e	A
Taxus buccata	Yew	705	7.79	14.3	11.9	9.5	1.2	1.7	8.7	7.8	6.4	4.7	3.7	3.0	–	–	–
Tectona grandis	Teak	660	9.97	15.5	12.9	10.3	1.2	1.6	9.4	8.3	6.8	4.5	3.5	2.8	I	e	B
Toena ciliata	Toon	487	6.40	8.7	7.3	5.8	0.7	1.0	5.4	4.8	3.9	2.4	1.8	1.5	II	c	B
Terminalia citrna		755	11.89	17.1	14.3	11.4	1.1	1.6	10.8	9.6	7.9	5.0	3.9	3.2	–	–	–
Terminalia myriocarpa	Hollock	615	9.62	11.9	9.9	8.0	0.9	1.2	7.6	6.7	5.5	2.9	2.2	1.8	III	a	B
Xylia dolabriformis	Lohakat	1007	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Xylocarpus rolloensis	Passur	757	–	–	–	–	–	–	–	–	–	–	–	–	–	–	B
Zanthoxylum budranga	Mullilam	587	10.65	14.7	12.2	9.8	0.9	1.2	9.5	8.4	6.9	3.4	2.6	2.1	I	e	B

Figure 48. Footnote (BNBC 2014, Table 11.4.1).

† Classification for preservation based on durability tests, etc.

Class

I – Average life more than 120 months;

II – Average life 60 months or above but less than 120 months; and

III – Average life less than 60 months.

‡ Treatability Grades

a – Heartwood easily treatable;

b – Heartwood treatable, but complete penetration not always obtained; in case where the least dimension is more than 60 mm;

c – Heartwood only partially treatable;

d – Heartwood refractory to treatment; and

e – Heartwood very refractory to treatment, penetration of preservative being practically nil even from the ends.

Data based on strength properties at three years of age of tree.

§ Classifications based on seasoning behavior of timber and refractoriness w.r.t. cracking , splitting and drying rate.

A – Highly refractory (slow and difficulty to season free from surface and end cracking);

B – Moderately refractory (may be seasoned free from surface and end cracking within reasonably short periods, given a little protection against rapid drying conditions); and

C – Non-refractory (may be rapidly seasoned free from surface and end-cracking even in the open air and sun. If not rapidly dried, they develop blue stain and mould on the surface.

There are a number of preferred cut sizes for use as structural components according to the BNBC 2014 Building Code. These material sizes vary based on their application, which includes roof trusses, roof purlins, rafters, floor beams, and partition framing, covering, and centering. These sizes are shown in Table 15, Table 16, and Table 17.

Table 15. Preferred cut sizes of structural timbers for roof trusses (span from 3 m to 20 m) (BNBC 2014 Table 11.4.5).

Thickness mm	Width mm							
1	2	3	4	5	6	7	8	9
20	40	50	60	80	100	–	–	–
25	40	50	60	80	100	120	160	180
30	40	50	60	80	100	120	160	180
35	–	–	60	80	100	120	160	180
40	–	–	60	80	100	120	160	180
50	–	–	60	80	100	120	160	180
60	–	–	–	80	100	120	160	180
80	–	–	–	–	100	120	160	180

NOTES

1 For truss spans marginally above 20 m, preferred cut sizes of structural timber may be allowed.

2 Preferred lengths of timbec 1, 1.5,2,2.5 and 3 m.

Table 16. Preferred cut sizes of structural timber for roof purlins, rafters, floor beams, etc. (BNBC 2014 Table 11.4.6).

Thickness mm	Width mm						
1	2	3	4	5	6	7	8
50	80	100	120	140	–	–	–
60	80	100	120	140	160	–	–
80	–	100	120	140	160	–	–
100	–	–	–	140	160	180	200

NOTE —Preferred lengths of timber: 1.5,2,2.5 and 3 m.

Table 17. Preferred cut sizes of structural timbers for partition framing and covering, and for centering (BNBC 2014 Table 11.4.7).

Thickness mm	Width mm								
1	2	3	4	5	6	7	8	9	10
10	40	50	60	80	–	–	–	–	–
15	40	50	60	80	100	–	–	–	–
20	40	50	60	80	100	120	160	200	–
25	40	50	60	80	100	120	160	200	240
30	40	50	60	80	100	120	160	200	240
40	40	–	60	80	100	120	160	200	240
50	–	50	–	80	100	120	160	200	240
60	–	–	60	80	100	120	160	200	240
80	–	–	–	80	100	120	160	200	240

5.3.2.1 Timber products

According to IS 5539 (1969) Amendment No. 4, the dimensions of plywood boards shall be:

- 2,400 mm x 1,200 mm (around 7'-10" x 3'-11")
- 2,100 mm x 1,200 mm (around 6'-11" x 3'-11")
- 1,800 mm x 1,200 mm (around 5'-11" x 3'-11")
- 2,100 mm x 900 mm (around 6'-11" x 3'-11")
- 1,800 mm x 900 mm (around 5'-11" x 2'-11")

Thicknesses shall be 3 mm, 4 mm, 5 mm, 6 mm, 8 mm, 9 mm, 12 mm, 15 mm, 19 mm, 22 mm, and 25 mm.

Tolerances for the length are -0 and +6 mm and for the width are -0 and +3 mm. For thicknesses less than 6 mm, ± 10% and for thicknesses 6 mm and above, ± 5% (IS 5539 [1969]).

Typical particle board thicknesses are estimated to be 9 mm, 12 mm, and 18 mm, based on collected data from particle board mills as part of the material database.

5.3.3 Construction material - bamboo

Bamboo construction is described in Part 6, Chapter 4 of the Bangladesh National Building Code (BNBC-2014). There are around 10–12 species of bamboo cultivated in village grows, which include *Bambusa tulda, Bambusa balcooa, Bambusa vulgaris, Oxytenanthera nigrociliata, Dendrocalamus longispathus*, and *Melocanna baccifera*. All three Bambusa species are widely produced in bamboo plantations and are very common across the country. Sixteen of these species are suitable for structural applications and are classified based on their extreme fiber stress in bending. All are classified as least concern, are data deficient, or have not been classified according to IUCN Red List of Endangered Species (IUCN Red List 2016). Table 18 and Table 19 list data on the species of bamboo recommended for structural purposes (BNBC 2014).

Table 18. Physical and mechanical properties of bamboos (in round form) (BNBC 2014, Table 6.4.5).

Sl No.	Species	Properties						
		In Green Condition				In Air Dry Conditions		
		Density kg/m3	Modulus of Rupture N/mm2	Modulus of Elasticity 103 N/mm2	Maximum Compressive strength N/mm2	Density kg/m3	Modulus of Rupture N/mm2	Modulus of Elasticity 103 N/mm2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	*Bambusa auriculata*	594	65.1	15.01	36.7	670	89.1	21.41
ii)	*B. balcooa*	740	64.2	7.06	38.6	850	68.3	9.12
iii)	*B. bambos (Syn.B.atwndinacea)*	559	58.3	5.95	35.3	663	80.1	8.96
iv)	*B. burmanica*	570	59.7	11.01	39.9	672	105.0	17.81
v)	*B. glancescens (Syn.B.nana)*	691	82.8	14.77	53.9	—	—	—
vi)	*B. nutans*	603	52.9	6.62	45.6	673	52.4	10.72
vii)	*B. pallida*	731	55.2	12.90	54.0	—	—	—
viii)	*B. polymorpha*	610	36.6	6.0	31.4	840	40.6	5.89
ix)	*B. tulda*	610	53.2	10.3	39.5	830	65.8	11.18
x)	*B. ventricosa*	626	34.1	3.38	36.1	—	—	—
xi)	*B. vulgaris*	626	41.5	2.87	38.6	—	—	—
xii)	*Cephalostachyum pergracile*	601	52.6	11.16	36.7	640	71.3	19.22
xiii)	*Dendrocalamus giganteous*	597	17.2	0.61	35.2	—	—	—
xiv)	*D. hamiltonii*	515	40.0	2.49	43.4	—	—	—
xv)	*D. longispathus*	711	33.1	5.51	42.1	684	47.8	6.06
xvi)	*D. membranacaus*	551	26.3	2.44	40.5	664	37.8	3.77
xvii)	*D. strictus*	631	73.4	11.98	35.9	728	119.1	15.00
xviii)	*Melocanna baccifera*	817	53.2	11.39	53.8	751	57.6	12.93
xix)	*Oxytenanthera abyssinicia*	688	83.6	14.96	46.6	—	—	—
xx)	*Oxytenanthera nigrociliata*	510	40.70	11.7	25.2	830	51.98	12.85
xxi)	*Thyrsostachys oliveri*	733	61.9	9.72	46.9	758	90.0	12.15

Table 19. Safe working stresses of bamboos for structural designing (BNBC 2014: Table 6.4.6).

Sl No.	Species	Extreme Fibre Stress in Bending N/mm^2	Modulus of Elasticity $10^3 N/mm^2$	Allowable Compressive Stress N/mm^2
(1)	(2)	(3)	(4)	(5)
	GROUP A			
i)	Barnbusa glancescens (syn. B. nana)	20.7	3.28	15.4
ii)	Dendrocalamus strictus	18.4	2.66	10.3
iii)	Oxytenanthera abyss inicia	20.9	3.31	13.3
	GROUP B			
iv)	Bambusa balcooa	16.05	1.62	13.3
v)	B. pallida	13.8	2.87	15.4
vi)	B. nutans	13.2	1.47	13.0
vii)	B. tulda	13.3	1.77	11.6
viii)	B. auriculata	16.3	3.34	10.5
ix)	B. burmanica	14.9	2.45	11.4
x)	Cephalostachyum pergraci[e	13.2	2.48	10.5
xi)	Melocanna baccifera (Syn. M. bambusoides)	13.3	2.53	15.4
xii)	Thyrsotachys oliveri	15.5	2.16	13.4
	GROUP C			
xiii)	Bambusa arundinacea (Syn. B. bambos)	14.6	1.32	10.1
xiv)	B. polymorpha	9.15	1.71	8.97
xv)	B. ventricosa	8.5	0.75	10.3
xvi)	B. vulgaris	10.4	0.64	11.0
xvii)	Dendrocalamus longispathus	8.3	1.22	12.0
xviii)	Oxytenanthera nigrociliata	10.18	2.6	7.2

NOTE — The values of stress in N/mm^2 have been obtained by converting the values in kgf/cm^2 by dividing the same by 10.

[1)]The values given pertain to testing of bamboo in green condition.

5.3.4 Construction material - preservatives

The main purpose of wood preservation is to preserve timber against the agents of deterioration by improving the natural durability and service life of wood through treatment in a solution that is toxic to fungi and insects. The choice of treatment depends on the timber species, the sapwood content, and the use after treatment (Rabbi et al. 2015).

According to IS 5539 (1969): there are four types of preservatives that shall be used for plywood protection, which include:

- Type 1: (Oil Type) Coal tar creosote with or without admixture with various grades of petroleum or other suitable oils having high boiling point
- Type 2: (Organic Solvent Type) Copper naphthenate, zinc naphthenate, pentachlorophenol, benzene hexachloride and dichlorodiphenyltrichloroethane (DDT)
- Type 3: (Water Soluble Non-fixing Type) Zinc chloride, boric acid, borax, sodium fluoride and sodium pentachlorophenate.
- Type 4: (Water Soluble Fixed Type) Copper-chrome-arsenate (CCA), acid-copper-chrome (ACC), chromated zinc chloride and copper-chrome-boric acid (CCB) (IS 5539 [1969]).

The typical treatment in Bangladesh is CCA, which is used for wood, bamboo and sungrass. However, the treatment with CCA is being replaced with CCB due to the low cost, availability, and environmentally conscious nature of the product (Rabbi et al. 2015). Compared to construction in the United States, CCA has been phased out of residential uses by the Environmental Protection Agency in 2004; however, existing structures are allowed to continue being sold and used. CCB is safe for humans because of its low toxicity. It also has the advantage of migrating much deeper into the wood after treatment (Lebow 2007).

5.3.5 Construction material – adhesives

Adhesives for wood construction include synthetic resin, cold setting casein, animal, and polyvinyl acetate dispersion glue. Standards are listed in BNBC Chapter 5, section 2.9.4.

According to IS 848 (2006), there are three different classifications for synthetic resins:

- Phenolic synthetic resin – a resin derived from the reaction of phenol with an aldehyde.
- Aminoplastic synthetic resin – a resin derived from the reaction of urea, thiourea, melamine or allied compounds or mixtures of these compounds with formaldehyde.

- Synthetic resin adhesive – a composition consisting of either phenolic synthetic resin or aminoplastic synthetic resin including any hardening agent, fortifier, filler or extender (IS 848 [2006]).

There are also thee different characteristics of types of synthetic resins which include:

- Boiling Water Proof (BWP), which make joints highly resistant to weather, cold, boiling water, steam, and dry heat.
- Boiling Water Resistant (BWR), which makes joints that will survive weather exposure for only a few years. It will also withstand cold water indefinitely and boiling water for a limited period.
- Moisture Resistant (MR), which makes joints with these adhesives withstand cold water for a long people and hot water for a limited time. However, MR fails in boiling water (IS 848 [2006]).

The most common adhesive in Bangladesh is a urea-formaldehyde, due to its lower cost. The adhesive can be classified as MR, and it is typically used for creating commercial grade plywood and particle board. The adhesive has a tendency to emit formaldehyde for a long period of time after production. The amount of urea-formaldehyde resin in a laminated product is much less than a panel board product (Phadke 2013).

The phenol formaldehyde resin is another common type which allows for a stronger bond compared to urea-based adhesives and is classified as BWR. It is commonly used to make exterior-grade and marine-grade plywood. Due to its high cost relative to urea-formaldehyde, extenders are added to reduce the amount of glue for penetrating veneer layers (Phadke 2013).

Formaldehyde poses potential human health hazards that occur during a high level of emissions. For plywood, the synthetic resins used contain formaldehyde, and so it cannot be considered eco-friendly as would a natural wood product. However, these emissions are reduced due to reductions over time and through proper finishing such as paint or laminates, which may help in making the product safer for use. Currently more eco-friendly solutions for adhesives are being researched to counter this concern (Scurlock at al. 2000).

5.3.6 Grade

The BNBC lists three different grades of wood for construction: Select Grade, Grade I, and Grade II. For each grade the wane is limited to 1/8, 1/6, and ¼ of the width, respectively. Worm holes (except for those due to powder post beetles) are permissible for all grades. The slope of the grain is less than 1 in 20, 1 in 15, and 1 in 12, respectively for each grade. Additionally, loose grains, splits, compression wood in coniferous species, heartwood rot, sap rot, and crookedness are not permissible for any grade. Defects in the timber should be oriented during construction in such a manner that avoids any adverse effects on the member.

Bamboo is graded based on a number of properties including diameter and length, taper, straightness, inner-nodal length, wall thickness, density and strength, and durability and seasoning.

5.3.7 Reported quality

There is no wood-based industry in Bangladesh that possesses facilities for timber seasoning except for a few enterprises and private industries and therefore, unseasoned timber is being used in almost all instances. A study of the wood seasoning practices in the wood furniture industry in three major cities in Bangladesh in 1988 reported that most of the seasoning practices were of poor quality. According to the results of the study, most of the industries produced partially dried wood (Table 20).

Table 20. Result of survey of drying practices for seasoning in major cities of Bangladesh ("Feasibility of a Wood Seasoning Plant" 2005).

Locality	No. of industries	Method	Range of mc reached		Seasoning condition
			Sawn timber	Manufactured	
Dhaka	30	Air drying	25- 50	18 - 35	Partially dried
	2	Kiln drying	16- 22	14 - 19	Almost seasoned
Chittagong	30	Air drying	30- 60	22 - 45	Partially dried
	4	Kiln drying	15- 20	14 - 20	Almost seasoned
Khulna	30	Air drying	25- 50	18 - 24	Partially dried
	1	Kiln drying	15- 22	14 - 20	Almost seasoned

Although the survey year in the figure is dated, over the years the condition of seasoning practice has not improved and has most likely worsened. Therefore, determining the moisture content of sawn and manufactured timber within Bangladesh is a necessary step in order to evaluate the condition of the material ("Feasibility of a Wood Seasoning Plant" 2005). If

left untreated, the wood is susceptible to termites, ants, and other wood-damaging insects (Porter 1991).

Most of sawmilling industries in Bangladesh operate at a primitive level compared to modern technology. In the sawmill industry, sawn materials are rough and vary in dimension across each board (Islam et al. 2013).

The useful life of bamboo in construction is very short, and it is typically replaced in a few years after application. This may be improved through better construction details and/or chemical preservations. However, preservatives are toxic, and one of the largest hurdles in preservation is avoiding health and environmental risks (Stulz and Wehrle 1992). Due to the scarcity of bamboo for use of low-income households, inferior quality bamboo is typically used, which results in more frequent maintenance and a hazard for those living in the homes.

5.3.8 Uses

Timber in Bangladesh is typically used on second stories or in buildings raised above the ground because the material may be susceptible to rotting. It is used for walling, roofing, doors, window frames, and shutters (Stouter 2008). Bamboo can be used as a substitute for timber in many applications. In fact, 90% of the bamboo harvest is used for structural support of houses or partitions and walls (de Vries 2002).

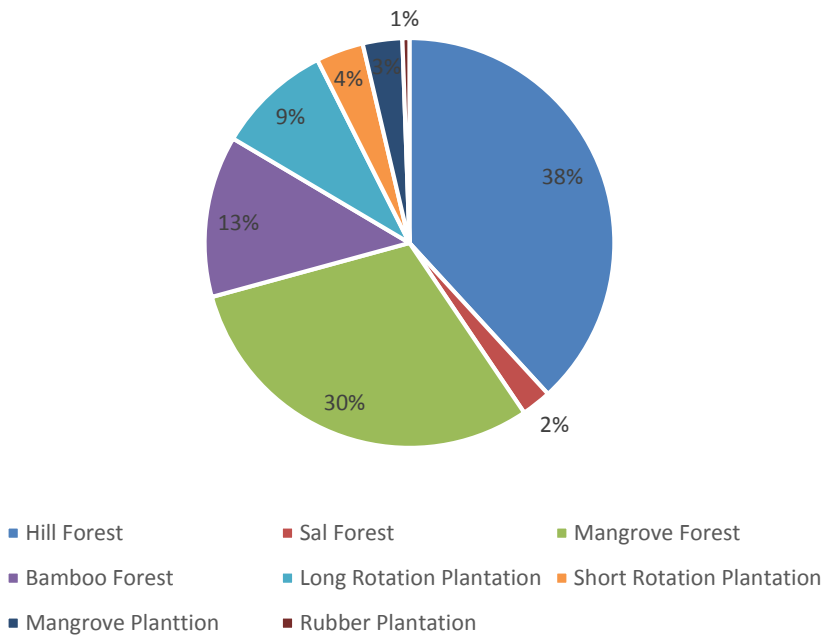
5.4 Production factors

5.4.1 Raw materials

Of the forestry in Bangladesh, 84% is natural forest while 16% is on plantations. Plantations are managed agricultural land where timber is cultivated, whereas natural forests consist of trees that grow without human interaction. The natural forests of Bangladesh are mostly in Chittagong and the Chittagong Hill Tracts (CHT), Cox's Bazar, Sylhet, Mymensingh, and Panchagar.

Within forestry there are a number of categories of forests, such as village, tropical moist-deciduous, tropical evergreen and semi-evergreen, mangrove forest, and community forests. Forests in Bangladesh can be divided according to Figure 49.

Figure 49. Forest cover percentage (Altrell et al. 2007).



The Sundarbans, which is located in the southwest region of Bangladesh, composes the largest single-tract mangrove forest in the world. It covers an area of 577,000 hectares (401.6K land, and 175.6K water bodies). Additionally, tropical evergreen and semi-evergreen forests cover the southern and eastern parts of the country. A small portion of forestland is located in the central and northern districts, yet it is more vulnerable to conversion to nonforestry uses and urbanization due to its close vicinity with Dhaka.

Overall, the forest land cover has been increasing each year; current estimates for forest are 6%–18% of land mass. The country does not have a well maintained database on the forestry and so there is uncertainty in this estimate (Rahman 2012).

The total supply of Bamboo in Bangladesh is around 722 million culms, which is around 194 million culms of public forests and 528 million culms of village forests (Govil 2000).

5.4.2 Imports and exports

Bangladesh is heavily dependent on imports of forest and forest products to meet demand (Govil 2000). The largest source of imports was originally Myanmar, which had met up to 70% of timber demands. However, the Ministry of Environmental and Conservation and Forestry in Myanmar

imposed an export ban on timber in effect from 01 April 2014. The forest had been shrinking (from 57.9% in 1990 to 47.6% in 2005), which led to the decision for this ban. The price had increased by around 0.38–0.64 cents per cubic foot due to travel distance (Choudhury 2016).

Bangladesh mostly imports wood construction materials rather than exports. The value of imported and exported product is shown in Table 21. The yearly total is estimated at $28 million in FY2013. The current largest source of import is Nigeria, which represents 26% of the value and is the leading source of densified wood. Nigeria is followed by Malaysia, the largest source of particle board; India, the largest source of veneer sheets; Canada, the largest source of sawn wood; and the United States. Bangladesh exports mostly particle board and sawn wood, which together compose 90% of the total wood construction exports (Simoes 2013).

Table 21. Imports and exports of wood products in FY 2013 (Simoes and Hidalgo 2011).

Imports and Exports of Wood	Product							
Country	Carpentry Wood	Densified Wood	Particle Board	Plywood	Rough Wood	Sawn Wood	Veneer Sheets	Wood Fiberboard	Grand Total
Export	**$ 11,200**	**$ -**	**$ 112,500**	**$ 11,990**	**$ -**	**$ 116,000**	**$ -**	**$ 3,400**	**$ 255,090**
Africa	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 116,000**	**$ -**	**$ -**	**$ 116,000**
Nigeria	$ -	$ -	$ -	$ -	$ -	$ 116,000	$ -	$ -	$ 116,000
Asia	**$ 11,200**	**$ -**	**$ 112,500**	**$ 3,330**	**$ -**	**$ -**	**$ -**	**$ 3,400**	**$ 130,430**
China	$ -	$ -	$ -	$ 3,330	$ -	$ -	$ -	$ -	$ 3,330
India	$ 11,200	$ -	$ 21,300	$ -	$ -	$ -	$ -	$ -	$ 32,500
Malaysia	$ -	$ -	$ 91,200	$ -	$ -	$ -	$ -	$ -	$ 91,200
Slovakia	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,400	$ 3,400
Europe	**$ -**	**$ -**	**$ -**	**$ 8,660**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 8,660**
France	$ -	$ -	$ -	$ 8,660	$ -	$ -	$ -	$ -	$ 8,660
Import	**$ 1,060,700**	**$ 6,874,350**	**$ 1,297,500**	**$ 2,812,000**	**$ 2,982,470**	**$ 5,474,280**	**$ 1,510,100**	**$ 6,178,690**	**$ 28,190,090**
Africa	**$ 15,400**	**$ 6,520,000**	**$ -**	**$ -**	**$ 2,199,000**	**$ 103,600**	**$ -**	**$ -**	**$ 8,838,000**
Cote D'Ivoire	$ -	$ -	$ -	$ -	$ 1,300,000	$ -	$ -	$ -	$ 1,300,000
Ghana	$ -	$ -	$ -	$ -	$ -	$ 87,400	$ -	$ -	$ 87,400
Mauritius	$ 15,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 15,400
Nigeria	$ -	$ 6,520,000	$ -	$ -	$ 899,000	$ -	$ -	$ -	$ 7,419,000
Republic of the Congo	$ -	$ -	$ -	$ -	$ -	$ 16,200	$ -	$ -	$ 16,200
Asia	**$ 635,900**	**$ 231,350**	**$ 1,257,600**	**$ 2,787,840**	**$ -**	**$ 1,186,230**	**$ 1,094,900**	**$ 6,178,690**	**$ 13,372,510**
China	$ 238,000	$ -	$ 58,600	$ 2,351,900	$ -	$ 21,200	$ 123,000	$ 1,666,950	$ 4,459,650
India	$ 14,700	$ 228,000	$ -	$ 25,100	$ -	$ -	$ 857,000	$ -	$ 1,124,800
Indonesia	$ 105,000	$ -	$ -	$ 10,400	$ -	$ 1,140,000	$ -	$ -	$ 1,255,400
Malaysia	$ 132,000	$ 3,350	$ 1,180,000	$ 289,000	$ -	$ 23,300	$ -	$ 3,980,000	$ 5,607,650
Pakistan	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,900	$ -	$ 13,900
Singapore	$ -	$ -	$ -	$ 103,000	$ -	$ -	$ -	$ 54,200	$ 157,200
South Korea	$ 48,600	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 48,600
Sri Lanka	$ -	$ -	$ -	$ 8,440	$ -	$ -	$ -	$ 2,340	$ 10,780
Thailand	$ 97,600	$ -	$ 19,000	$ -	$ -	$ 1,730	$ -	$ 400,000	$ 518,330
Vietnam	$ -	$ -	$ -	$ -	$ -	$ -	$ 101,000	$ 75,200	$ 176,200
Europe	**$ 30,400**	**$ 123,000**	**$ 39,900**	**$ 7,460**	**$ 183,470**	**$ 541,950**	**$ 104,100**	**$ -**	**$ 1,030,280**
Denmark	$ -	$ -	$ -	$ -	$ -	$ 82,700	$ -	$ -	$ 82,700
Germany	$ -	$ -	$ -	$ -	$ 124,000	$ 368,000	$ 21,500	$ -	$ 513,500
Italy	$ -	$ 123,000	$ 39,900	$ 7,460	$ 42,400	$ -	$ 82,600	$ -	$ 295,360
Poland	$ -	$ -	$ -	$ -	$ -	$ 83,600	$ -	$ -	$ 83,600
Spain	$ -	$ -	$ -	$ -	$ 10,600	$ -	$ -	$ -	$ 10,600
Sweden	$ 30,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 30,400
Switzerland	$ -	$ -	$ -	$ -	$ 6,470	$ 7,650	$ -	$ -	$ 14,120
North America	**$ -**	**$ -**	**$ -**	**$ 3,000**	**$ 584,400**	**$ 3,552,000**	**$ 311,100**	**$ -**	**$ 4,450,500**
Canada	$ -	$ -	$ -	$ -	$ 21,500	$ 2,570,000	$ 26,100	$ -	$ 2,617,600
Costa Rica	$ -	$ -	$ -	$ -	$ 24,900	$ -	$ -	$ -	$ 24,900
United States	$ -	$ -	$ -	$ 3,000	$ 538,000	$ 982,000	$ 285,000	$ -	$ 1,808,000
Oceania	**$ 379,000**	**$ -**	**$ -**	**$ 13,700**	**$ -**	**$ 90,500**	**$ -**	**$ -**	**$ 483,200**
Australia	$ 379,000	$ -	$ -	$ 13,700	$ -	$ -	$ -	$ -	$ 392,700
New Zealand	$ -	$ -	$ -	$ -	$ -	$ 90,500	$ -	$ -	$ 90,500
South America	**$ -**	**$ -**	**$ -**	**$ -**	**$ 15,600**	**$ -**	**$ -**	**$ -**	**$ 15,600**
Argentina	$ -	$ -	$ -	$ -	$ 1,400	$ -	$ -	$ -	$ 1,400
Ecuador	$ -	$ -	$ -	$ -	$ 14,200	$ -	$ -	$ -	$ 14,200

5.4.3 Production process

Logs are converted to sawed lumber through debarking, which occurs when the log enters a sawmill on a conveyor. A headsaw, or the first saw, is used to remove slabs and some boards. One of three different types of saws are used: a band saw, a frame (gang) saw, or a circular saw. A band saw is composed of a continuous band of steel with teeth on a single edge which moves around two wheels. Frame saws consist of a reciprocating frame where saw blades are parallel to each other at a predetermined distance. A circular saw has a circular blade with teeth in the periphery and is mounted on a shaft.

The second sawing process re-saws the thick boards into smaller-size boards. Edging, or the removal of the edge areas of bark or parts of missing wood and is typically done by a set of circular blades. Lastly, crosscutting is performed to square the ends and remove defects.

The wood is then graded based on strength and appearance. The rest is scrapped to produce sawdust, slabs, trimmings or chips, or typically is burned to produce energy.[16]

Raw timber contains a high moisture content, ranging from 50% to 80% in its dry weight. Wood in Bangladesh is dried to a level that is in equilibrium with atmospheric temperature and humidity. The average equilibrium moisture content is 12%–14% in Bangladesh. The moisture content must not be more than 14% for interior use and not more than 18% for exterior uses according to IS-5539 (1969).

Wood is seasoned before being manufactured to improve its mechanical and physical properties, dimensional stability, finishing, polishing, painting, and gluing capacity. Seasoning helps to avoid deterioration from fungus and insects, and it thus enhances the life of the product. There are three common methods used in seasoning: air drying, kiln drying, and solar drying.

[16] Encyclopedia Britannica. Online edition, s.v. “Wood”. Accessed 15 January 2016. http://www.britannica.com/science/wood-plant-tissue.

5.4.3.1 Air drying

Air drying is seasoning wood through exposure to direct sunlight or underneath a shed, following proper stacking. According to the Technical Specifications for Buildings Section 2.10 (2005), the recommended width and height of a stack is 1.5 m and 2.0 m, respectively, while the minimum distance between stacks is 0.8 m. The air-drying method relies on natural flow of air, sunshine, and rain. The method is the most simple and inexpensive, yet it requires a long time and takes up a larger volume of space compared to other drying methods.

5.4.3.2 Kiln drying

Kiln drying is seasoning of timber through an enclosed chamber, with full control of drying elements (heating, humidification, air circulation, and ventilation). The timber can be dried to a lower level of moisture content in any time of year. Commercial timbers throughout the world are seasoned through this method; kiln drying is efficient, but expensive and complex to install and operate. When improperly seasoned, there may be defects or complete damage of the timber. There are 55 conventional seasoning kilns in 20 organizations in Bangladesh, with a total capacity of around 0.71 million cubic feet per year; however, these kilns are not fully utilized due to lack of technical knowledge, improper maintenance, and other factors, so some are not in operation.

5.4.3.3 Solar drying

Solar drying is drying of timber in a fully enclosed structure which derives energy from solar radiation with assistance from a heat absorber. The solar radiation is transmitted through a glazing material, which traps radiation inside the kiln to be used as heat energy to season the wood. Public and private companies in Bangladesh constructed 22 solar kilns with a total capacity of 36,000 cubic feet per year; however, most are out of operation because they have reached the end of their 10-year life and were not reconstructed ("Feasibility of a Wood Seasoning Plant" 2005). Upon drying, the wood is then treated.

5.4.3.4 Treatment by pressure impregnation after manufacture

This method is widely used in Bangladesh, as well as the rest of the world, because it is the most permanent manner of preserving timber life. The method is most suitable for large-scale production, since the equipment

and energy costs are the largest disadvantages of the method. Different process types include full cell, fluctuation pressure, Boucherie, and high-pressure sap displacement (Rabbi et al. 2015).

Through the process, the timber is placed in a pressure cylinder where it is stacked vertically or horizontally with spacers or grills between the sheets. After creating a vacuum, the preservative is introduced and absorbed by the wood. For plywood, because of the partial permeability of the veneer and glue lines, plywood can be penetrated from the ends of the veneer. This penetration varies based on the permeability of the timber used in the veneer and shall be such that the structure of the wood is not damaged.

5.4.3.5 Treatment by soaking or surface application of preservative after manufacture

This method is very simple and can be performed by anyone. Surface applications are completed by using a brush or spray, or through dipping in preservative solution for a short period; at least two coats are applied. Soaking applications are long, with people submerging of plywood until required absorption is obtained. Through the method of hot and cold dipping, the wood is first placed into a hot solution until cooled, and then it is placed in a cold solution of the same preservative.

5.4.3.6 Treatment of dry or wet veneers before assembly

If timber used in plywood is noncompliant to treatment, treatment is difficult after manufacture. The veneers themselves can be almost fully penetrated with preservatives and may be treated through soaking and diffusion for wet veneers. The adhesive used must be compatible with the preservative treatment through this method.

Other methods of preservation in Bangladesh include charring, applying preservatives in bored holes, diffusion processes, and sap displacement.

5.4.3.7 Treatment of bamboo

In Bangladesh, bamboo is treated by submerging it in water with a small amount of borax for 21 days, after which it is dried in the shade for seven days to resist termite infection, and then, the bamboo is given a smoke treatment. Rapid drying in the open sun is another method that can control decay due to fungal and insect attack. After the project is completed, a

layer of varnish is applied to allow for further longevity. The bamboo can usually last if there is no rain or other effects from water (Stouter 2008).

5.4.4 Power

Sawmills are usually driven by a 15kW electric motor, however this can range from 11.25 kW–18.75 kW, using either V-belt or flat-belt drive. Sawmill units operate on a part-time basis, with production being reduced through nonavailability of logs, power failures, mechanical breakdowns, and saw sharpening in situ (Islam et al. 2013).

6 Steel

Steel is the most widely used building material and has other practical uses in many industries. Steel is a popular material because of its relatively low cost of production, formation, and processing; the abundance of iron ore and scrap metal; and its range of mechanical properties. Steel is a metal alloy of iron and carbon which has a carbon content from 0%–2%. The carbon content, heat treatment, and added alloy elements determine the properties of the material. There are many options for microstructure, shape, and surface finishes available for steel as a product. There are several thousand steel grades which are standardized, registered, or published globally. Steel is formed into either flat or long products, which are either hot-rolled, cold-rolled, or coated on the surface. Flat products are plates, strip, and sheets while long products are made of either blooms or billets.17

Steel is considered to be a sustainable material. It can be recycled many times without incurring the effects of degradation in properties or performance. There is little-to-no waste during steel production. Byproducts include blast furnace slag cement and gas. The increased use of steel scrap in production creates less dependence on the raw materials, iron ore and coal. Over 80% of steel beams are composed of scrap steel. Compared to concrete, steel has a high strength-to-weight ratio, which allows for smaller foundations in steel-framed buildings. Steel is also a viable solution for long span structures, which offers more flexibility for change during a building's life (Islam et al. 2016).

6.1 Industry

6.1.1 Global scenario

World steel production in 2013 was around 1.6 billion tons. Globally, the most steel is produced and used in China. Specifically, carbon steel is the most produced and used product, and it represents around 90% of world steel production.18 There is a significant and continued growth worldwide of the construction industry which prevents demand for steel to be met

[17] Britannica Academia, Online ed., s.v., "Steel." Accessed 15 January 2016. http://www.britannica.com/technology/steel.

[18] ibid.

solely by recycling of end-of-life products and so, virgin iron is necessary to convert into steel.

6.1.2 Background

The first steel mill in the land of Bangladesh was established in 1952 by the Bangladesh Steel Re-Rolling Mills (commonly known as BSRM) in Nasirabad, Chittagong, much before the country gained its independence in 1971. Since then, the Bangladesh steel industry has emerged as one of the major industrial sectors in the country and consists of small- to large-scale steel factories around the country. The revolution and development in the steel industry occurred in the 1990s, when building construction agencies or developer companies strived to build modern infrastructure.

Currently, the average growth rate of the steel industry has been 6%, however this number is expected to grow to 10% over the next few years. The construction industry as a whole has a calculated average growth rate (CAGR) of 12.2% (Hasan 2013).

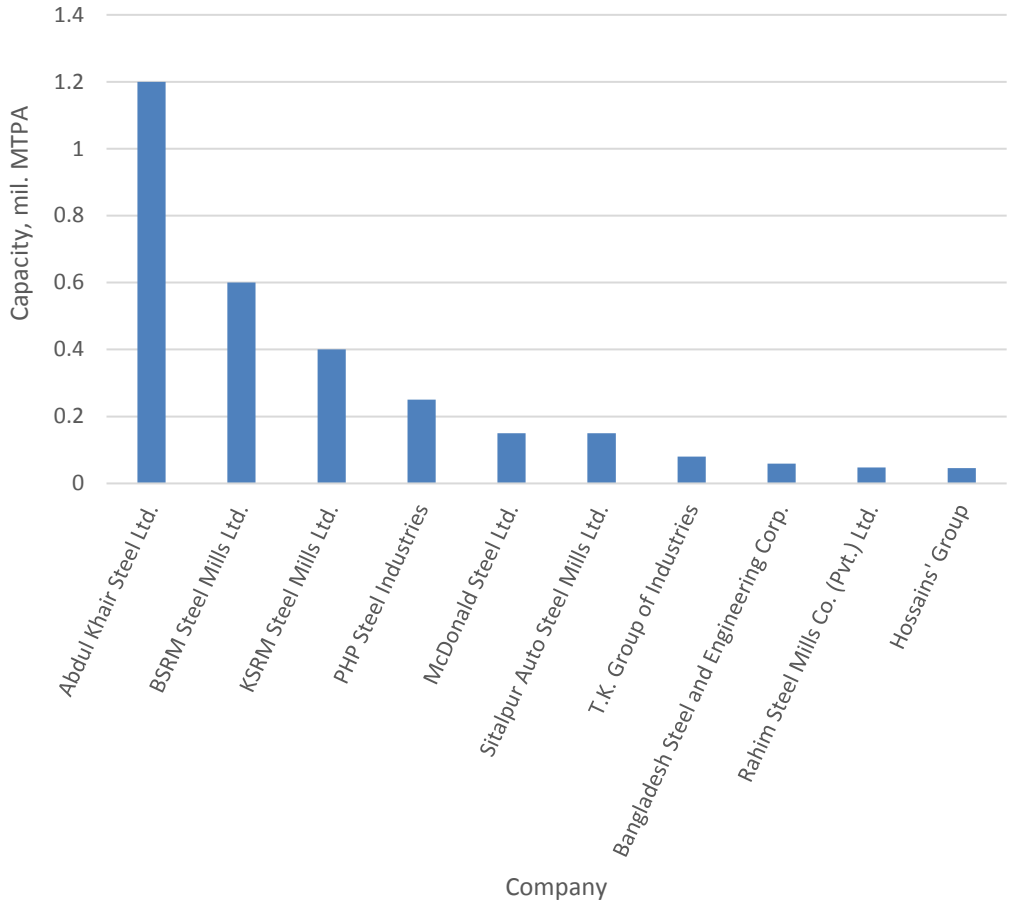
6.1.3 Producers

There are more than 400 steel mills of different categories and sizes operating within the country. Most of the plants are manual while only 30 mills are automated. The yearly production of a typical, medium-sized plant is estimated to be 0.0112 million MTPA for scrap melting and 0.016 million MTPA for rerolling.19

The top 10 companies and their installed capacities are shown in Figure 50. The figure was formed from a collection of capacities of steel companies from a variety of data sources within the material database. These data sources are included within the database itself. Abdul Khair Steel Ltd. (AKS) is currently the highest-producing steel company. The top three companies—AKS, BSRM, and KSRM—together produce 2.2 million MTPA (compared to the demand of 3.5–4 million MTPA).

[19] Britannica Academia, Online ed., s.v., "Steel." Accessed 15 January 2016. http://www.britannica.com/technology/steel.

Figure 50. Capacity of prominent steel producers in Bangladesh, FY2015 (ERDC-CERL, 2016).[20]



There are a number of challenges in the growth of the steel industry, as listed here:

- *Competitive market*: newly invested companies have started operation while existing companies are expanding on existing capacity, making it difficult to newcomers.
- *Economic crunch*: 2008 recession, socio-political situation, and 2011 stock market crash have stagnated development works in the real estate sector, causing the supply to outpace demand.
- *High borrowing cost and exchange rate risk*: high interest rate of banks and financial institutions contributes to reduced profit margins of steel-producing companies.

[20] Capacity data is limited to companies with published production data.

- *Energy crisis*: steelmaking has exhaustive power requirements, needs a constant power supply, and requires gas production; lack of energy resources slows down growth of industry.
- *Technology risk*: many still use manual production methods, mills cannot compete with automated factories in terms of cost, efficiency, and production volume.
- *Environmental risk*: Bangladesh possesses no iron ore deposits or mines, therefore ship scrapping is a major source of raw materials. However environmental standards for ship breakers (2011 Ship Breaking and Recycling Rules act) has caused this component of the industry to come to a halt with high demand (Hasan 2013).

6.1.4 Consumers

Bangladesh consumes 4 million MTPA of steel. The per capita consumption in Bangladesh is 25 kg, which is less than the neighboring country of India (55 kg). Compared to the world per capita average of 206 kg, this quantity is relatively small. The government accounts for close to 40% of steel consumption. Other domestic consumers of steel products include but are not limited to contractors, property developers, export processing zones, road and bridge construction companies, and shipbuilding companies. The supply of steel tends to be larger than the demand (Hasan 2013).

6.1.5 Locations of construction material

The locations of steel mills and corporate offices are shown in Figure 51 and Figure 52. Factories of steel and rerolling mills are mostly located in the Dhaka and Chittagong regions.

In Dhaka, mills are mostly located in Narayangaj in the south and are along major roads and riverways. Corporate offices are located in the city center of Dhaka. Steel demand in the capital city necessitates having a supply centered around the core construction area, where high steel demand exists. Areas of activity include Demra, Shampur, Matuail, Gazipur, Rupganj and Modonganj (Hasan 2013). Locations of steel sites within the Dhaka region can be found in Figure 53 and Figure 54.

In Chittagong, mills are spatially close to the shipbreaking industry and are almost entirely located along the coast of the Bay of Bengal. Corporate offices are located in the city center of Chittagong. Regions of major steel activity include Bhaitari, Fousdarhat, Kumira, Baizid Bostami, and

Nasirabad (Hasan 2013). Locations of steel sites within the Chittagong region can be found in Figure 55 and Figure 56.

Because of the connectivity between Dhaka and Chittagong, a number of mills and offices are located along the Dhaka-Chittagong highway, which makes the transportation of the metal economically feasible.

With regard to general steel shapes and rebar, there is a large overlap between the centers of activity of the two products. Rebar is more highly produced, and so there are generally more steel mills producing the product than steel shapes, because reinforced concrete is a more common construction material for the country.

Figure 51. Locations of steel shapes in Bangladesh [green: office, orange: plant] (Google Maps, 2016).

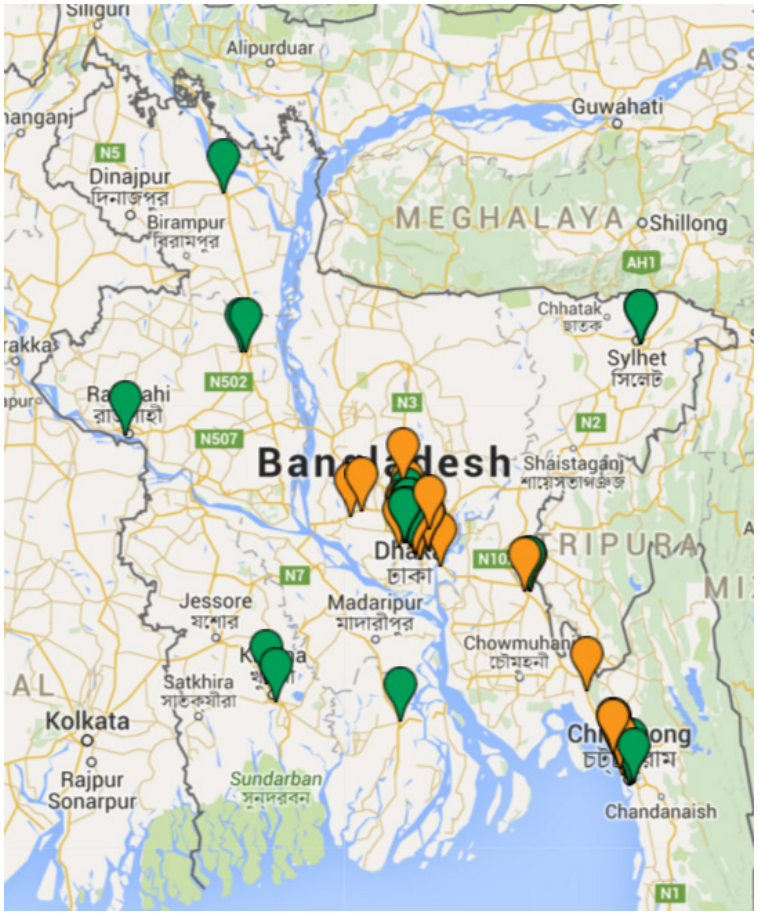


Figure 52. Locations of steel rebar in Bangladesh [green: office, orange: plant] (Google Maps, 2016).

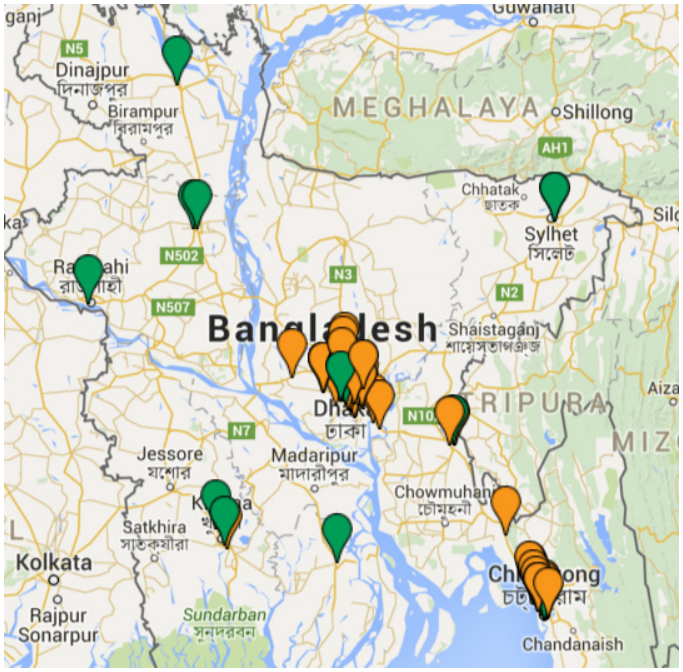


Figure 53. Locations of steel shapes in Dhaka, Bangladesh [green: office, orange: plant] (Google Maps, 2016).

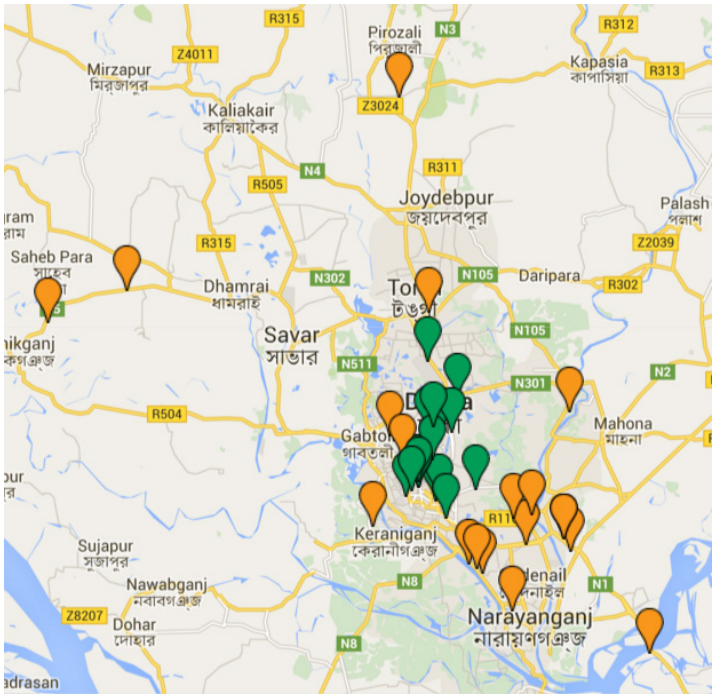


Figure 54. Locations of steel rebar in Dhaka, Bangladesh [green: office, orange: plant] (Google Maps, 2016).

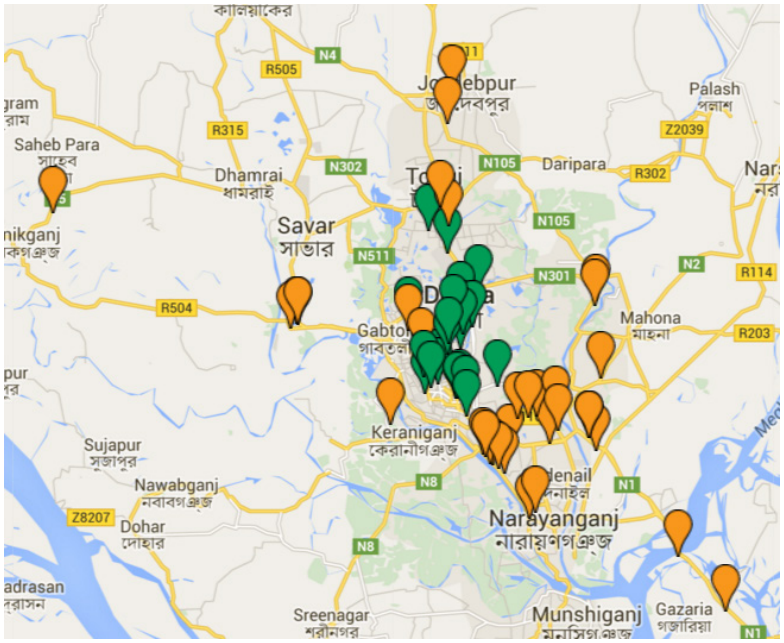


Figure 55. Locations of steel shapes in Chittagong, Bangladesh [green: office, orange: plant, blue: deposit] (Google Maps, 2016).

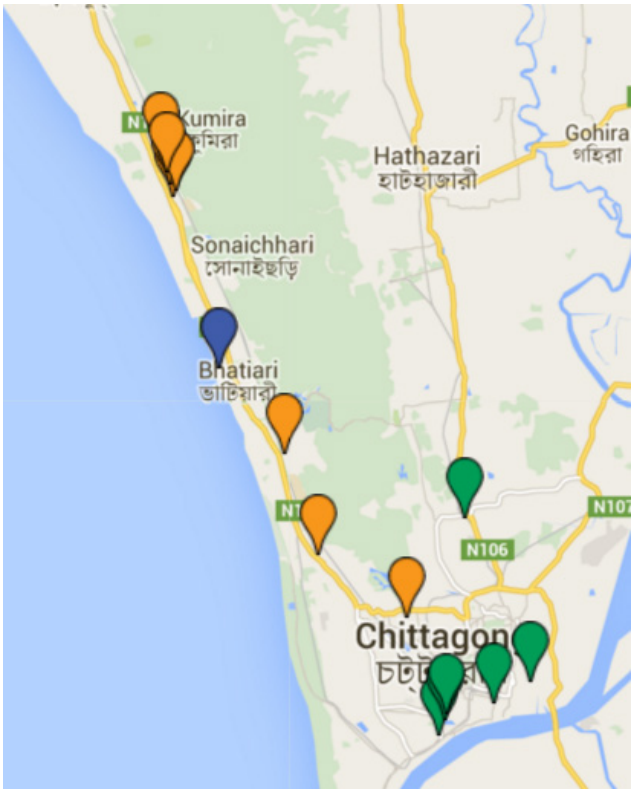
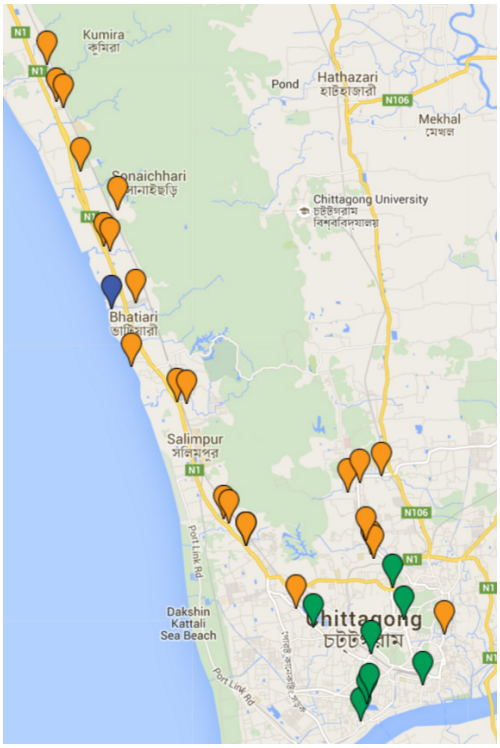


Figure 56. Locations of steel rebar in Chittagong, Bangladesh [green: office, orange: plant, blue: deposit] (Google Maps, 2016).



6.1.6 Construction material industry in India

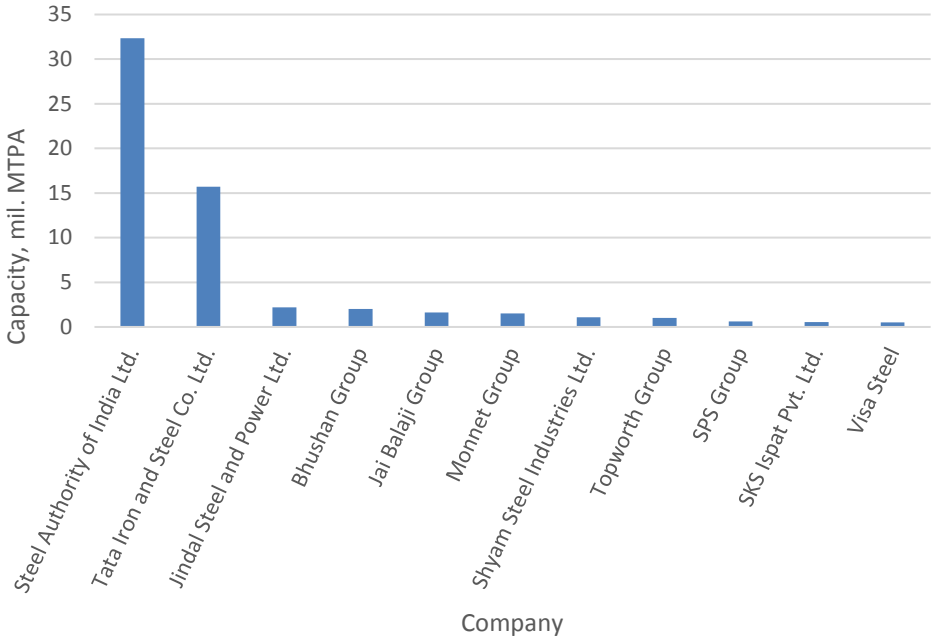
The Indian steel sector is around a century old and is important to the economy in India due to the rising demand in infrastructure and other markets. The steel industry is divided into two sectors: the primary sector, which is composed of a few large integrated steel producers, and the secondary sector, which includes small units focused on production of value-added products.[21] The country is the fourth-largest producer of crude steel and the largest producer of soft iron in the world ("Steel Industry of India" 2016).

The top 11 companies in east and northeast India and their installed capacities are shown in Figure 57. The figure was formed from a collection of capacities of steel companies from a variety of data sources within the material database. These data sources are included within the database itself.

[21] Value-added products are those where the physical state of a product is altered to produce a new product. Integrated steel producers refer to mills which use iron ore as a basic material to produce crude steel, which becomes rolled steel.

The largest current steel producer in east India is the Steel Authority of India, Ltd. (SAIL), which has locations in West Bengal, Odissa, Assam, and Chhattisgarh and is part of the public sector. All other companies in East India are in the private sector. The second largest is Tata Iron and Steel Co. Ltd. These two companies comprise the majority of the steel industry in the region. There are also a number of smaller-sized plants with very small capacity (less than 2 million MTPA) This data is expected to change over the coming years, with many larger companies currently expanding into east India for steel production.

Figure 57. Capacity of prominent steel producers in east India, FY2015 (ERDC-CERL, 2016).[22]



Similar to Bangladesh, raw materials for steel in India originate from a shipbreaking yard, which located on the western side of the country. Unlike Bangladesh, India possesses the additional resource of iron ore deposits for steel production, particularly in the region of Odissa. Many of the steel mills are located closer to the Bay of Bengal and Odissa. An overview of the locations of steel in India is shown in Figure 58 and Figure 59. There are very few mills in northeast India because of the limited access to raw materials. Also, similar to Bangladesh, there is overlap between the locations of steel shapes and rebar, with many plants producing both products. Centers of activity include Durgapur, Asanol,

[22] Capacity data is limited to companies with published production data.

Durg, Raipur, Raigarh, Jharsuguda, Rourkela, and Kolkata, which are shown in Figure 60, Figure 61, Figure 62, and Figure 63.

Figure 58. Locations of steel shapes in India [green: office, orange: plant] (Google Maps, 2016).

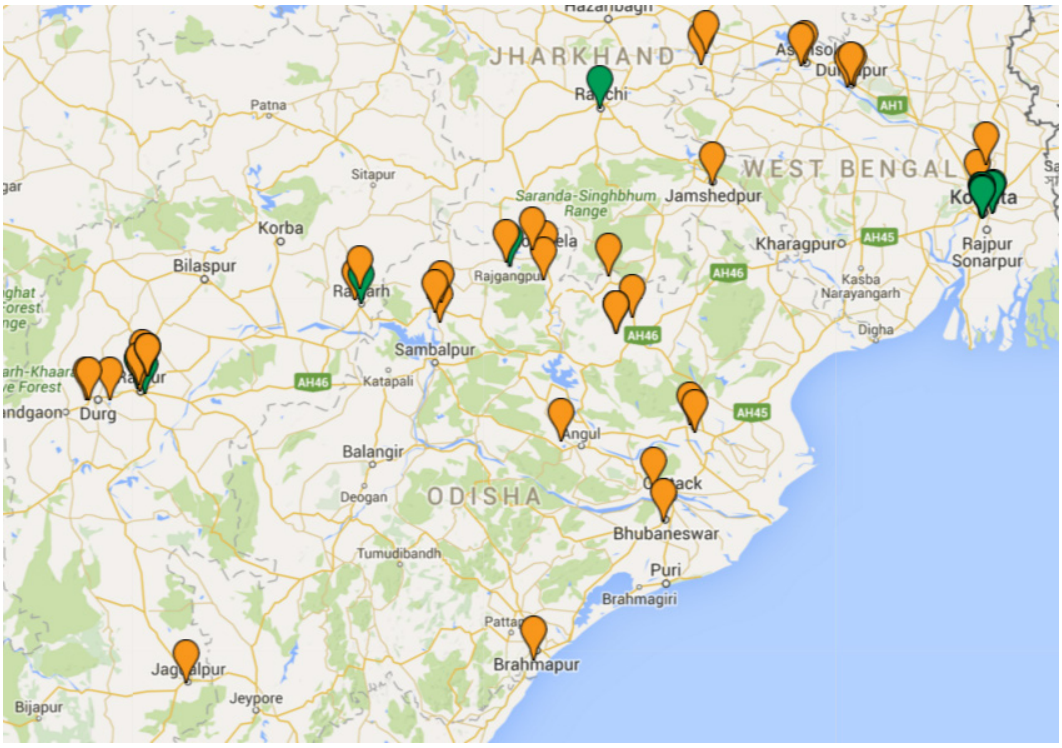


Figure 59. Locations of steel rebar in India [green: office, orange: plant] (Google Maps, 2016).

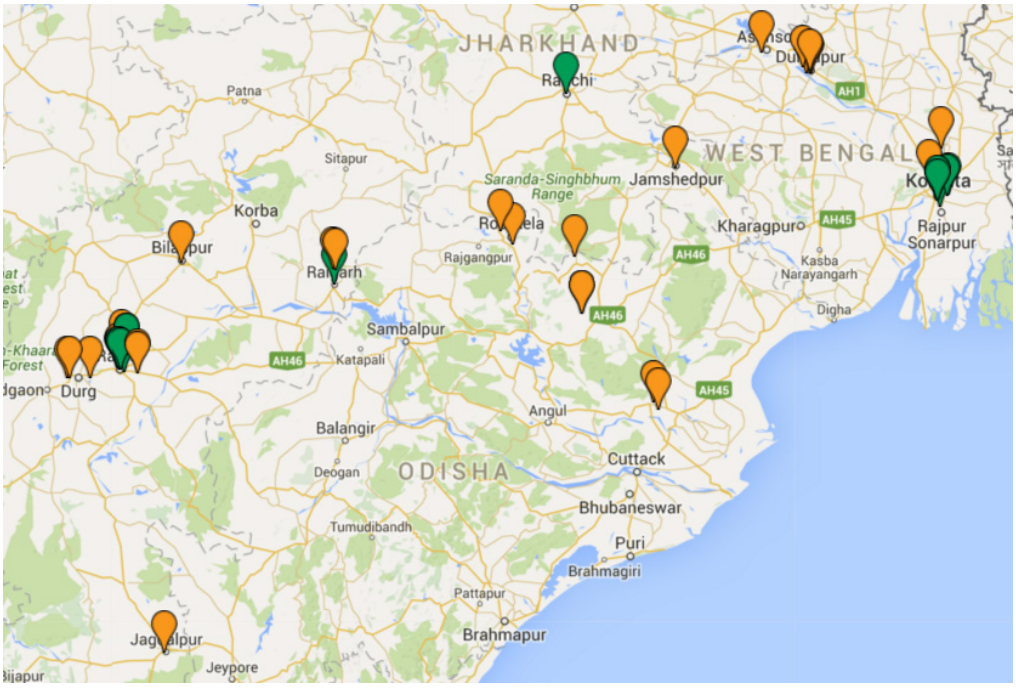


Figure 60. Locations of steel (Durgapur and Asanol, West Bengal, east India) [orange: plant] (Google Maps, 2016).

Figure 61. Locations of steel (Durg and Raipur, Chhattisgarh, east India) [green: office, orange: plant] (Google Maps, 2016).

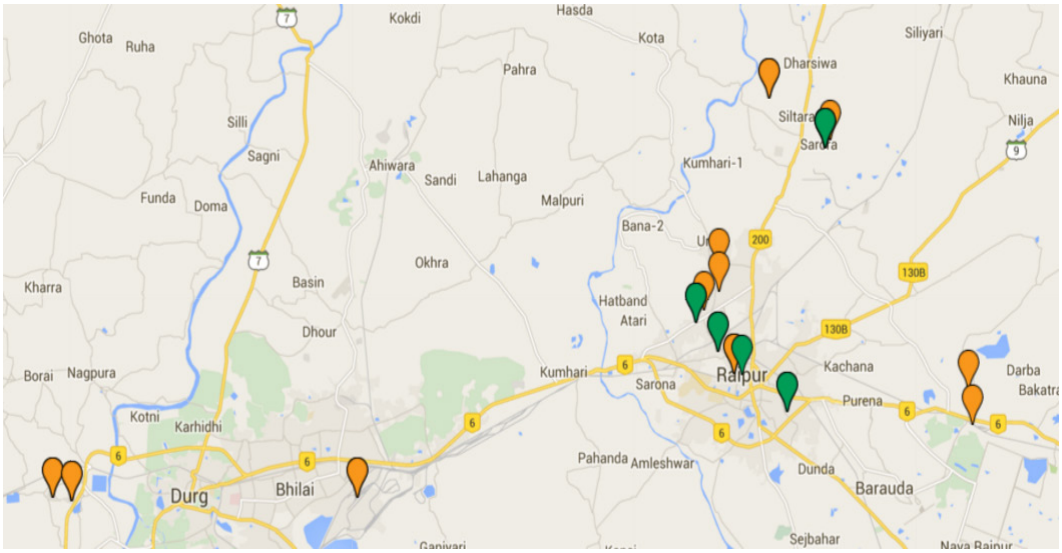
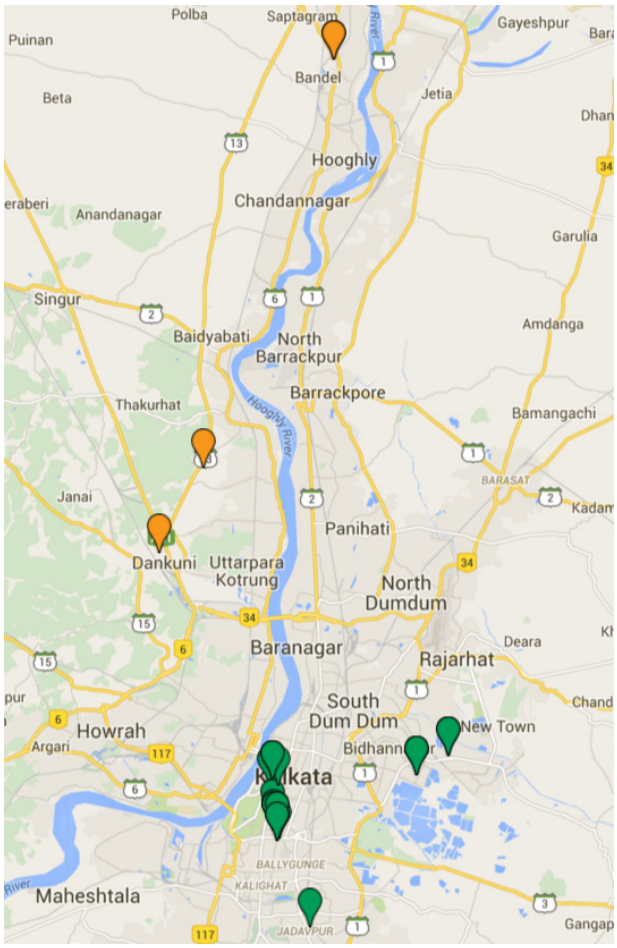


Figure 62. Locations of steel (Raigarh, Jharsuguda, Rourkela; Chhattisgarh, Orissa; E. India) [green: office, orange: plant] (Google Maps, 2016).

Figure 63. Locations of steel (Kolkata; West Bengal E. India) [green: office, orange: plant] (Google Maps, 2016).



6.2 Product

6.2.1 Codes, standards, and methods

The construction sector in Bangladesh follows the international standard of steel construction in order to maintain a quality product with respect to other developed countries. Steel design is provided in Part 6, Chapter 10 of BNBC-2014 code. According to the code, steel material from an acceptable testing laboratory shall conform to ASTM standards, based on the applicability. A selection of these standards are shown below for specific products.[23]

- Hot-rolled structural shapes: ASTM A36/A36M, ASTM A529/ A529M, ASTM A572/A572M, ASTM A588/A588M, ASTM A709/ A709M, ASTM A913/A913M, ASTM A992/ A992M
- Structural tubing: ASTM A500, ASTM A501, ASTM A618, ASTM A847, BDS 1031:2006
- Pipe: ASTM A53/A53M, Gr. B, BDS 1031:2006
- Plates: ASTM A36/A36M, ASTM A242/A242M, ASTM A283/ A283M, ASTM A514/A514M, ASTM A529/A529M, ASTM A572/ A572M, ASTM A588/A588M, ASTM A709/A709M, ASTM A852/A852M, ASTM A1011/A1011M, BDS 1122:1987 Reaffirmed 2007
- Bars: ASTM A36/A36M, ASTM A529/A529M, ASTM A572/A572M, ASTM A709/A709M, BDS ISO 6935-1:2006, BDS ISO 6935-2:2006
- Sheets: ASTM A606, A1011/A1011M SS, HSLAS, AND HSLAS-F, BDS 1122:1987 Reaffirmed 2007

Nominal dimensions for structural steel sections are provided by the BIS and can be found in the SP 6-1 (1964): ISI Handbook for Structural Engineers – Part-1 Structural Steel Sections (BNBC 2014).

6.2.2 Construction material

There are a number of different types of steel products manufactured in Bangladesh, as listed below:

6.2.2.1 Semi-finished casting products

- Billet

[23] "All Standards & Publications," ASTM International. Accessed June 21, 2016. http://www.astm.org/Standard/index.html.

- Bloom
- Slab
- Ingot

6.2.2.2 Finished casting products

- Wide-flange shape (W)
- American standard beam (S)
- American standard channel (C)
- Angle (L)
- Structural tee (WT or ST)
- Pipe
- Tubing
- Bar
- Plate

Additionally, a new product called a thermo-mechanically treated (TMT) bar is starting to be used in construction. This product provides production advantages compared to traditional types of steel, since no twisting operation is involved in production, resulting in no residual stresses and increased corrosion resistance (Hasan 2013).

6.2.3 Grade

There are three main grades of deformed bar produced in Bangladesh, which include Grades 40, 60, and 500 steel: 40 grade yields at 40 ksi strength, 60 grade yields at 60 ksi strength, and 500W yields at 500 MPa strength (72.5 ksi) (Hasan 2013). Some companies in the country produce 550W grade bars, which have a yield strength of 80 ksi.

6.2.4 Quality standards

The quality of good steel is determined based on the chemical composition, cleanliness and gas content. The quality is ranked according to the following carbon level, which is tested using an ultrasonic thickness machine (UTM). This quality spectrum is shown in Table 22.

Table 22. Quality of steel based on carbon level (Hasan 2013).

Carbon Equivalent (CE)	Weldability
0 to 0.35	Excellent
0.36-0.40	Very Good
0.41-0.45	Good
0.46-0.50	Fair
Over 0.50	Poor

Source: Seminar on Quality Steel and Its Importance in Civil Engineering Applications, BSRM

According to the BNBC, materials produced by the fabricator shall be of quality that is at least equal to that of the ASTM specifications. The material test reports shall be accepted as sufficient record of quality of materials taken from stock by the fabricator. Materials that are produced under no particular specification or a less rigorous specification shall not be used without approval of owner's structural design representative.

6.2.5 Uses

Steel is used for a variety of structural purposes in Bangladesh, including framing, beams, girders, columns, footings, trusses, arches, and domes.

6.2.5.1 Connections

There are four types of steel connections or joints used globally, which include pins, rivets, bolts, and welds. Pins are classified as smooth large-diameter fasteners without a thread. These are not very common in Bangladesh. Rivets are permanent mechanical fasteners. This technique was used extensively in the past; however, it has been replaced by welds and bolts. Bolts are a connection suitable for almost any type of section and are very commonly used in Bangladesh. Welding is used to join two metal sections through heating and/or pressure application. This connection is commonly used in Bangladesh (Islam et al. 2016).

6.2.5.2 Structural systems

Steel as a material is used in four major construction activities including the foundation, columns, beams, and slabs of a building structure. As part of a study on several structural systems for buildings in Bangladesh, the

reported construction and material costs allow for conclusions to be made on each system. These costs are shown in Figure 64 and Figure 65.

It was observed that for a steel-framed building with a composite floor and a steel-framed building with a precast floor, the maximum material cost is associated with the beams and slabs, and the maximum construction cost is associated with post-tensioned beam erection. For precast frame with precast concrete floor structures, the maximum material cost is associated with beams and slabs, and the maximum construction cost is in erection of slab panels (Islam et al. 2016).

Figure 64. Material cost of a building in Bangladesh (Islam et al. 2016).

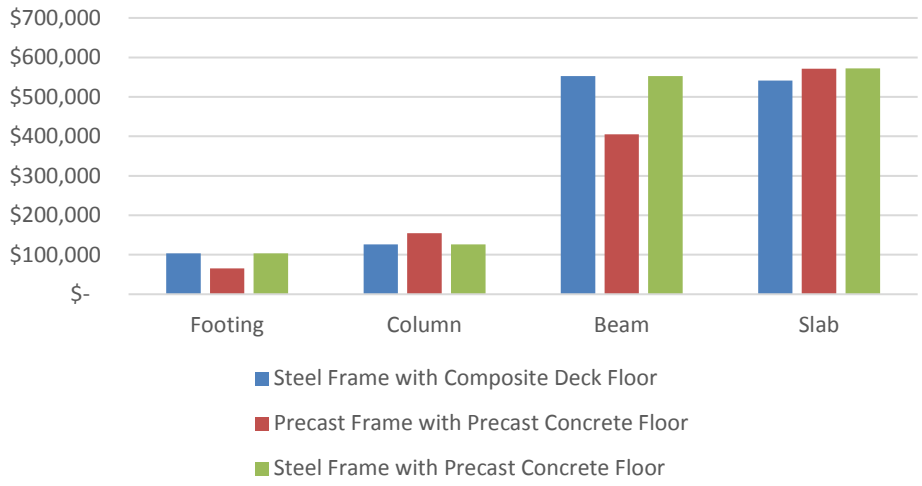
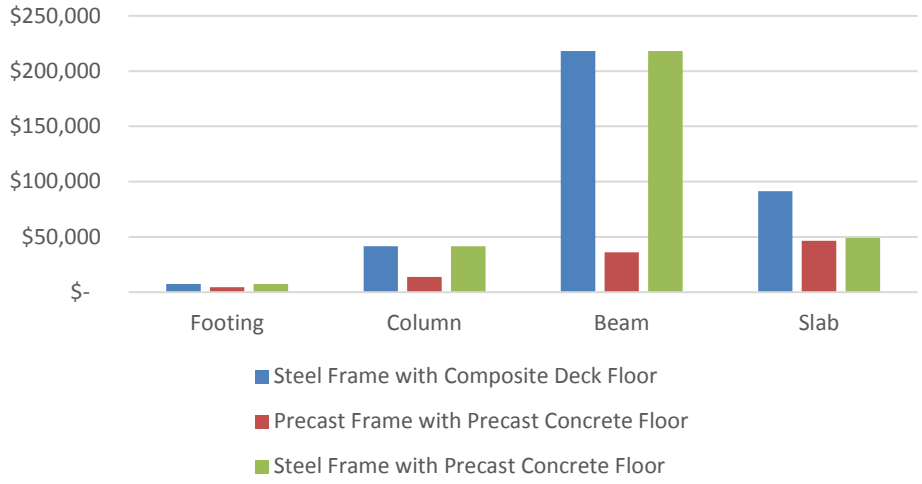


Figure 65. Construction cost of a building in Bangladesh (Islam et al. 2016).



When comparing structural system costs, a precast frame with precast concrete floor has around 23.1% savings, compared with a steel frame with a composite deck. A steel frame with precast concrete floor has around 0.52% savings compared with a steel frame with composite deck floor. A precast concrete frame with a precast concrete floor has 22.7% savings compared to a steel frame with precast concrete floor. With large span post-tensioned composite steel beams, the project cost increases by 11%. The cost of foundations and columns is relativity small in comparison with beams and slabs. The cost of steel building is higher than concrete because of the higher cost of the material (Islam et al. 2016).

6.3 Production factors

6.3.1 Imports and exports

Exports of steel products are shown in Table 23. Bangladesh exports product almost entirely to Asian countries. They export mostly cold-rolled iron product, where Indonesia receives around 60% of the exports, followed by India with 34% of the product. The largest recipient of scrap iron is India, which receives almost all of the raw material (99%). Bangladesh exports a relatively small amount of flat-rolled iron. Sri Lanka receives the largest amount of flat-rolled iron product or 56% of export.

Table 23. Exports of iron products, FY 2013 (Simoes 2013).

Exports	Product			
Country	Cold-Rolled Iron	Scrap Iron	Flat-Rolled Iron	Grand Total
Export	**$ 18,360,000**	**$ 10,064,830**	**$ 1,292,500**	**$ 29,717,330**
Asia	**$ 18,360,000**	**$ 10,033,930**	**$ 1,292,500**	**$ 29,686,430**
Indonesia	$ 11,000,000	$ -	$ -	$ 11,000,000
India	$ -	$ 9,930,000	$ 60,500	$ 9,990,500
Singapore	$ 6,220,000	$ 58,500	$ -	$ 6,278,500
Sri Lanka	$ -	$ -	$ 731,000	$ 731,000
Cambodia	$ 711,000	$ -	$ -	$ 711,000
Ghana	$ -	$ -	$ 385,000	$ 385,000
Malaysia	$ 288,000	$ -	$ -	$ 288,000
Thailand	$ 141,000	$ -	$ -	$ 141,000
Malawi	$ -	$ -	$ 116,000	$ 116,000
Japan	$ -	$ 42,300	$ -	$ 42,300
Pakistan	$ -	$ 3,130	$ -	$ 3,130
Europe	**$ -**	**$ 30,900**	**$ -**	**$ 30,900**
Netherlands	$ -	$ 30,900	$ -	$ 30,900

Imports of steel products are shown in Table 24. Bangladesh imports a wide variety of iron products from across the globe. The largest source of iron product imports is Japan, followed by India and South Korea. The largest imported product is semi-finished iron, which is imported mostly from India, followed by Russia and the Ukraine. The second-largest imported product is hot-rolled iron, which comes from Japan, India, and South Korea. Following closely behind hot-rolled iron is flat-rolled iron as the third-largest imported product, which originates mostly from Japan, China, and South Korea.

Table 24. Imports of iron products, FY 2013 (Simoes 2013).

Imports	Product					
Country	Cold-Rolled Iron	Hot-Rolled Iron	Scrap Iron	Semi-Finished Iron	Flat-Rolled Iron	Grand Total
Import	**$ 19,616,920**	**$ 354,486,200**	**$ 113,655,000**	**$ 411,524,090**	**$ 342,448,490**	**$ 1,241,730,700**
Africa	**$ -**	**$ -**	**$ 1,035,000**	**$ -**	**$ 2,491,600**	**$ 3,526,600**
South Africa	$ -	$ -	$ 477,000	$ -	$ 2,480,000	$ 2,957,000
Egypt	$ -	$ -	$ 558,000	$ -	$ -	$ 558,000
Tanzania	$ -	$ -	$ -	$ -	$ 11,600	$ 11,600
Asia	**$ 4,265,020**	**$ 338,670,300**	**$ 8,789,000**	**$ 248,482,680**	**$ 235,616,900**	**$ 835,823,900**
Japan	$ 2,820,000	$ 188,000,000	$ -	$ 15,562,600	$ 100,039,800	$ 306,422,400
India	$ 3,020	$ 65,900,000	$ 136,000	$ 115,221,000	$ 7,682,800	$ 188,942,820
South Korea	$ 630,000	$ 77,420,300	$ -	$ 48,540,000	$ 48,275,000	$ 174,865,300
China	$ 575,000	$ 1,653,000	$ -	$ 2,224,080	$ 65,830,000	$ 70,282,080
Turkey	$ -	$ -	$ -	$ 56,400,000	$ 19,200	$ 56,419,200
Malaysia	$ -	$ 177,000	$ -	$ 10,400,000	$ 4,012,500	$ 14,589,500
Vietnam	$ -	$ 1,060,000	$ -	$ -	$ 6,146,000	$ 7,206,000
Thailand	$ -	$ -	$ 3,950,000	$ -	$ 2,418,000	$ 6,368,000
Singapore	$ 237,000	$ -	$ 4,190,000	$ 135,000	$ 1,170,300	$ 5,732,300
Indonesia	$ -	$ 4,460,000	$ -	$ -	$ -	$ 4,460,000
Phillippines	$ -	$ -	$ 499,000	$ -	$ -	$ 499,000
Sri Lanka	$ -	$ -	$ -	$ -	$ 23,300	$ 23,300
Jordan	$ -	$ -	$ 14,000	$ -	$ -	$ 14,000
Europe	**$ 8,421,900**	**$ 11,365,900**	**$ 63,043,000**	**$ 132,127,010**	**$ 47,575,290**	**$ 262,533,100**
Russia	$ -	$ -	$ -	$ 65,800,000	$ -	$ 65,800,000
Ukraine	$ -	$ -	$ -	$ 61,200,000	$ -	$ 61,200,000
United Kingdom	$ -	$ -	$ 38,500,000	$ 21,600	$ 1,104,800	$ 39,626,400
Belgium-Luxembourg	$ 1,770,000	$ 4,882,700	$ 2,420,000	$ -	$ 25,530,000	$ 34,602,700
Netherlands	$ 4,580,000	$ 1,440,000	$ 4,400,000	$ 86,200	$ 7,047,000	$ 17,553,200
Sweden	$ 972,000	$ 2,960,000	$ 6,680,000	$ 9,210	$ 2,858,450	$ 13,479,660
Germany	$ 83,500	$ 444,000	$ 2,470,000	$ -	$ 4,874,000	$ 7,871,500
Bosnia and Herzegovina	$ -	$ -	$ -	$ 5,010,000	$ -	$ 5,010,000
Italy	$ 905,000	$ 1,020,000	$ -	$ -	$ 2,805,800	$ 4,730,800
Poland	$ -	$ -	$ 3,010,000	$ -	$ 32,100	$ 3,042,100
France	$ -	$ 179,000	$ 381,000	$ -	$ 1,808,400	$ 2,368,400
Estonia	$ -	$ -	$ 2,020,000	$ -	$ -	$ 2,020,000
Latvia	$ -	$ -	$ 1,820,000	$ -	$ -	$ 1,820,000
Spain	$ 98,500	$ 385,000	$ -	$ -	$ 438,000	$ 921,500
Finland	$ 12,900	$ -	$ 404,000	$ -	$ 383,000	$ 799,900
Ireland	$ -	$ -	$ 644,000	$ -	$ -	$ 644,000
Czech Republic	$ -	$ -	$ -	$ -	$ 475,000	$ 475,000
Denmark	$ -	$ -	$ 294,000	$ -	$ -	$ 294,000
Slovakia	$ -	$ -	$ -	$ -	$ 115,000	$ 115,000
Greece	$ -	$ -	$ -	$ -	$ 91,800	$ 91,800
Austria	$ -	$ 55,200	$ -	$ -	$ -	$ 55,200
Switzerland	$ -	$ -	$ -	$ -	$ 11,940	$ 11,940
North America	**$ 6,930,000**	**$ 4,450,000**	**$ 36,170,000**	**$ 30,914,400**	**$ 56,749,600**	**$ 135,214,000**
Canada	$ 4,430,000	$ 2,730,000	$ 9,070,000	$ 30,900,000	$ 41,854,100	$ 88,984,100
United States	$ 2,500,000	$ 1,720,000	$ 27,100,000	$ 14,400	$ 14,834,000	$ 46,168,400
Mexico	$ -	$ -	$ -	$ -	$ 61,500	$ 61,500
Oceania	**$ -**	**$ -**	**$ 2,978,000**	**$ -**	**$ 15,100**	**$ 2,993,100**
Australia	$ -	$ -	$ 2,130,000	$ -	$ 15,100	$ 2,145,100
New Zealand	$ -	$ -	$ 848,000	$ -	$ -	$ 848,000
South America	**$ -**	**$ -**	**$ 1,640,000**	**$ -**	**$ -**	**$ 1,640,000**
Brazil	$ -	$ -	$ 1,640,000	$ -	$ -	$ 1,640,000

6.3.2 Technology

There are two major processes in steel production: the conventional process and the alternative process. The method of production depends on the type of raw materials that are used.

6.3.2.1 Conventional process

The conventional process accounts for 65% of world steel production and is used to produce steel from iron ore. Production from iron ore requires 7,400 MJ of energy. There are three steps in production, as listed below:

1. The blast iron furnace is set to the proper temperature and containment measures.
2. Iron ore is placed in the furnace and melted at around 1700 ˚C, which melts the scrap, lowers the carbon content, and removes unwanted chemical elements. Pure oxygen is used instead of air.
3. Molten iron is processed through a variety of means to produce steel.

6.3.2.2 Alternative process

The alternative process accounts for 35% of world steel production and is used to produce steel from scrap metals. Plants using this method are known as mini steel plants. The method is typically used in countries with low-cost labor, such as Bangladesh, India, and Indonesia (Kusumaningdyah et al. 2013). Production from scrap-iron metal needs 1,350 MJ of energy, which makes it a much less energy-intensive option than the conventional process.

Scrap metals are melted, and impurities are removed either through a direct reduced iron or sponge iron, and the metal is cast into desired shapes. This method involves the use of an electric arc furnace (EAF), which melts scrap metal in the presence of electric energy and oxygen (Hasan 2013).

6.3.3 Transportation and distribution

In Chittagong, traders buy from Chittagong shipbreaking yards in wholesale quantities and sell to businessmen in smaller quantities. These traders specialize in certain kinds of scraps. Only plain sheets are purchased from shipyards by businessmen in Dhaka, which are transferred from the yards (around 185 miles away). Almost all businessmen in Dhaka depend on scraps from these Chittagong yards. The expansion of family businesses and deployment of relatives as intermediaries are a factor in having drawn resources from Chittagong shipyards to Dhaka. Once in Dhaka, there are thousands of small- and medium-sized firms that process the scrap metal. The area is famous for specialized skill and knowledge as well as social and cultural attributes (Mizanur Rahman and Mayer 2015).

6.3.4 Power

Energy is consumed by mills in the form of electricity and thermal energy for heating. Reheating furnaces use natural gas while arc/induction furnaces use electricity. Most companies use grid electricity, and most mills have standby generation capacity. The process of melting is the most energy-intensive process in steelmaking.

For a typical, medium-sized plant in Bangladesh with 320 production days, the electricity consumption can be divided into two production lines: one for scrap melting and one for rerolling. For scrap melting, electricity consumption is approximately 700 kilowatt hours (kWh) per ton. For rerolling, the gas consumption is approximately 615 kWh per ton("NAMA Proposal" 2014).

7 Recycled Steel and Iron Ore

7.1 Industry

7.1.1 Global scenario

Recycling steel through the process of shipbreaking was originally carried out in industrialized ports in the United States and the United Kingdom until well into the 20th century. Afterward, the major centers of the shipbreaking and recycling industry (SBRI) moved to East Asia, and since the 1980s to South Asia. The major center of activity is in Bangladesh, India, and Pakistan, which together account for 70%–80% of the international recycling market. The remainder of the industry is covered by China and Turkey.

7.1.2 Background

The scrap-metal recycling industry began in Bangladesh in the 1970s. The Fauzdarhat Ship Breaking Yard in Chittagong is the largest shipbreaking area in the world, and it was introduced in 1969. The yard employs 200,000 Bangladeshis, and it accounts for 60% of steel production in Bangladesh due to the unavailability of quality coke and iron ire. The industry plays a key economic role in Bangladesh. At a macroscale, the need to meet demand, the weakness of the Bangladesh currency, and the lack of environmental regulations has driven the shipbreaking industry (Mizanur Rahman and Mayer 2015; Hasan 2015).

The SBRI has had a major social impact on Bangladesh. Most workers are migrants from poorer regions of Bangladesh. The hazardous nature of the job, and the variations in employment levels are a major reason for employment of migrant labor. Historically, working conditions have been poor, due to exposure to hazardous materials and unsafe conditions, which have led to fatalities and injuries (Sarraf et al. 2010).

7.1.3 Producers

The official association of shipbreakers is the Bangladesh Ship Breakers Association; almost all of the shipbreakers in Chittagong are members. The shipbreaking industry is based on a balance of business competition and tight-knit social ties. Family members are typically recruited to max-

imize strong ties (Hasan 2013). As of 2010, there are 119 active shipbreaking yards in Chittagong (up from 57 in 2008). The output from the yards is almost all used locally in Bangladesh (Sarraf et al. 2010).

7.1.4 Cyclicality

The supply of vessels for scrapping from the shipping sector is subject to large variations, depending on the global demand for sea transport. During periods of high demand, older ships are kept in operation and therefore, fewer vessels are offered for scrapping. On average, 700–800 ships are scrapped annually. However during shipping industry boom years, this figure is reduced to 300–400 vessels (Sarraf et al. 2010).

7.1.5 Locations of construction material

The key location of shipbreaking yards is in Chittagong because of the access to the Bay of Bengal ("Ship Recycling" 2011). The shipbreaking yard location can be found in Figure 66. Around half of the Chittagong shipbreaking yards are in the Sitakunda Thana region, which stretches for around 12–13 miles along the coast. Figure 67 shows an aerial photograph of a section of the shipyard.

Figure 66. Chittagong shipbreaking yard (Google Maps, 2016).

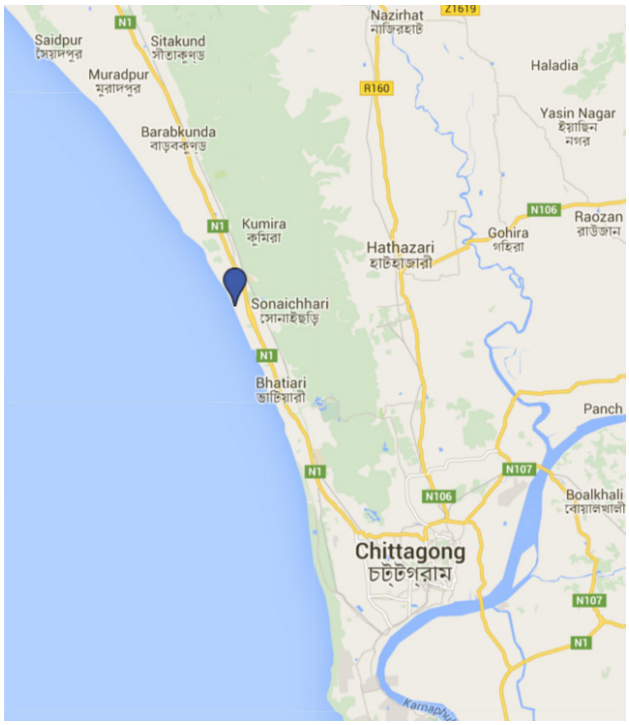
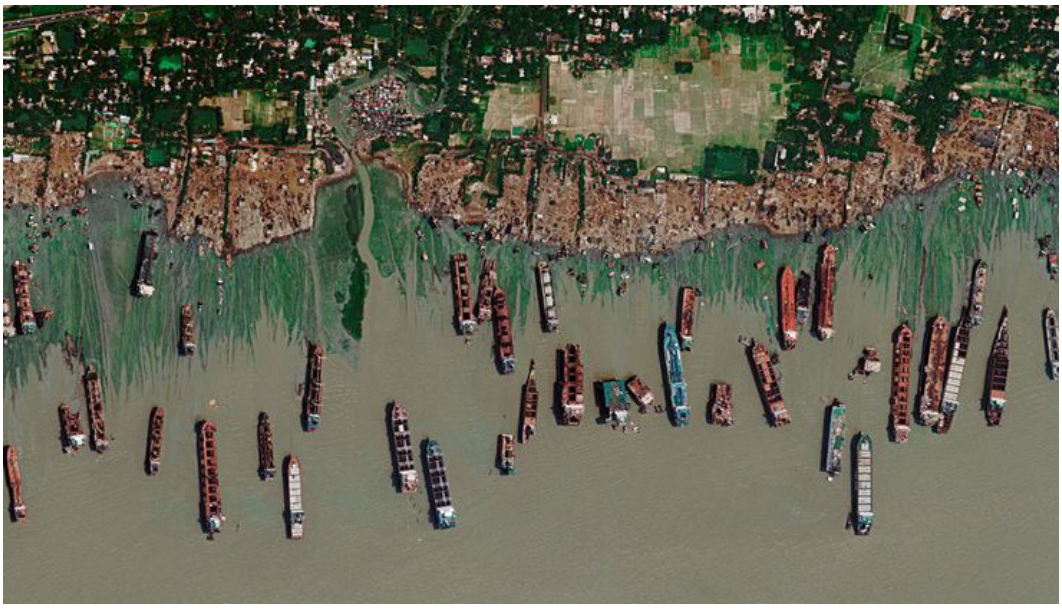


Figure 67. Aerial view of a section of Chittagong shipbreaking yard.[24]

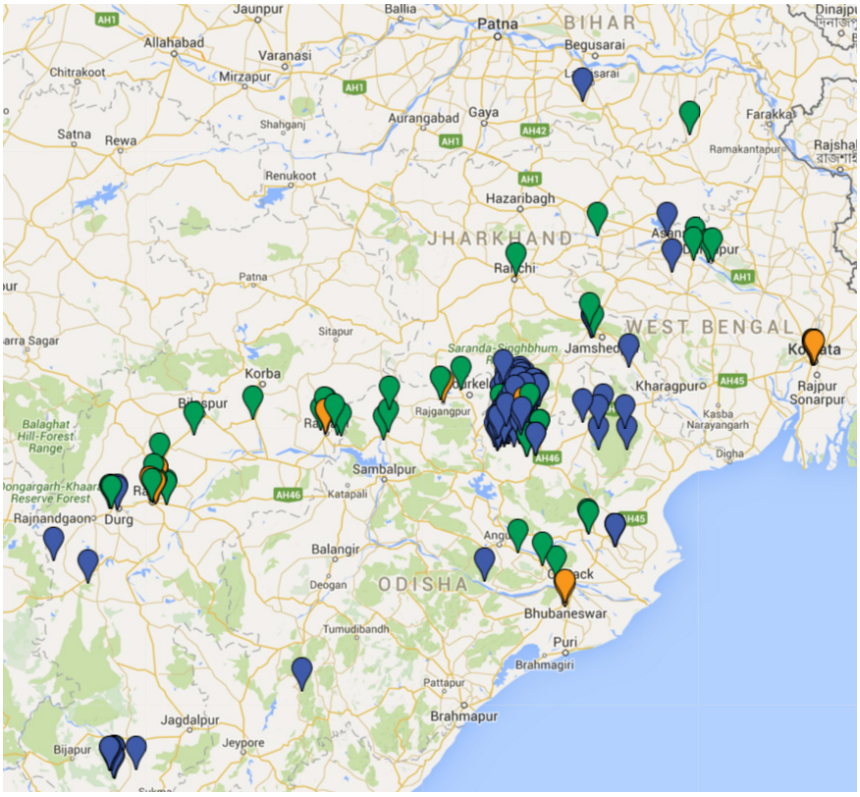


7.1.6 Construction material industry in India

Locations of iron ore in east India are shown in Figure 68. Iron ore deposits are mostly located within Odissa, particularly along the Odissa/Jharkhand border. Sponge Iron plants are generally located close to iron ore resources and closer to the Bay of Bengal. Centers of activity include Durgapur, West Bengal; Cuttack, Odissa; Raipur, Chhattisgarh; and Raigarh, Chhattisgarh. There are a very limited number plants and iron ore mines in northeast India.

[24] "The Ship-Breakers," National Geographic, accessed June 21, 2016. http://s.ngm.com/2014/05/shipbreakers/hettwer-photography.

Figure 68. Locations of iron ore in east India [orange: office, green: plant, blue: deposit] (Google Maps, 2016).



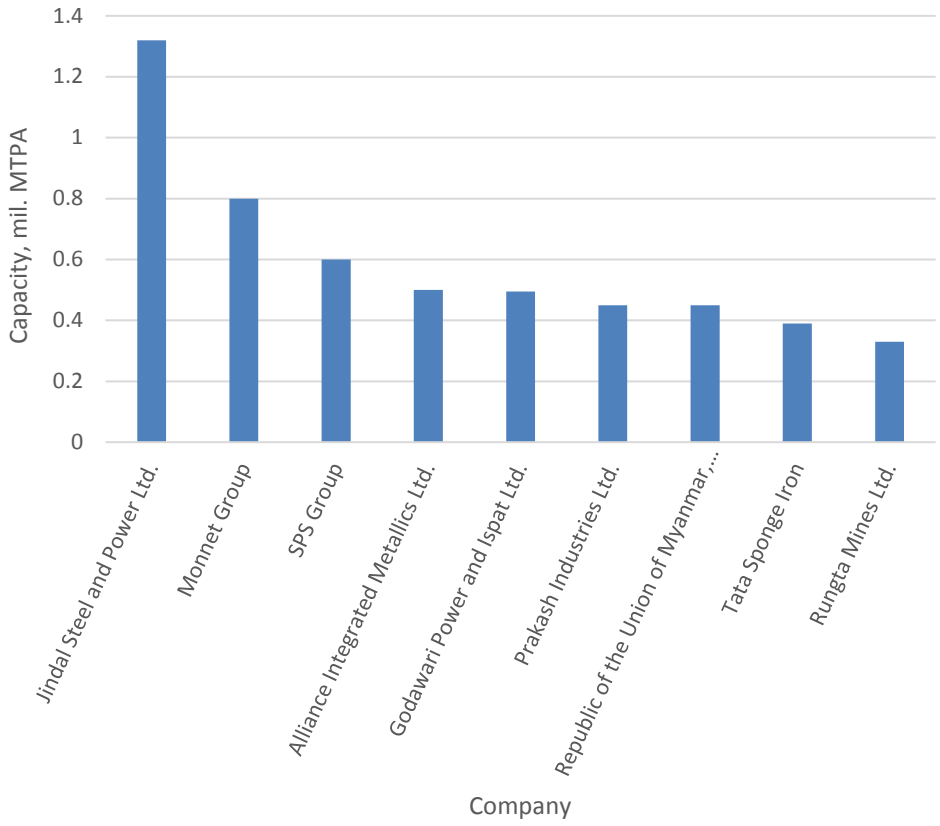
As a method of production for iron ore resources in the region, the sponge iron industry in India was promoted in the early 1990s. The industry is an alternative to steel scrap melting, which due to its scarcity had to be imported in large quantities and used for steelmaking. Today, India as a country is the largest producer of sponge iron in the world. The method itself is a common production approach in the Middle East, South America, India, and Mexico. Natural gas and coal are the two main fuel sources for direct-reduced iron (DRI) production, with coal as the primary fuel for eastern India ("Indian Minerals Yearbook 2012" 2014).

During the process of direct reduction, iron is extracted from ore at a temperature below the melting point of the material. The DRI can be processed to produce wrought iron, where it is removed from an EAF called a bloomer, beaten with hammers to remove slag, oxidize carbon, and weld the iron together. This is an energy-efficient alternative to making steel from scrap metal. The method is also attractive for small-scale production

due to the low investment requirements and the suitability to local raw material situations..[25]

The top nine companies and their installed capacities for steel production are shown in Figure 69. The figure was formed from a collection of capacities of cement companies from a variety of data sources within the material database. These data sources are included within the database itself. In East India, the largest producer of sponge iron is Jindal Steel and Power Ltd, with a capacity of 1.32 million MTPA. Most of the companies are around the same size and produce less than 0.5 million MTPA of sponge iron.

Figure 69. Capacity of prominent steel producers in East India, FY2015 (ERDC-CERL).[26]



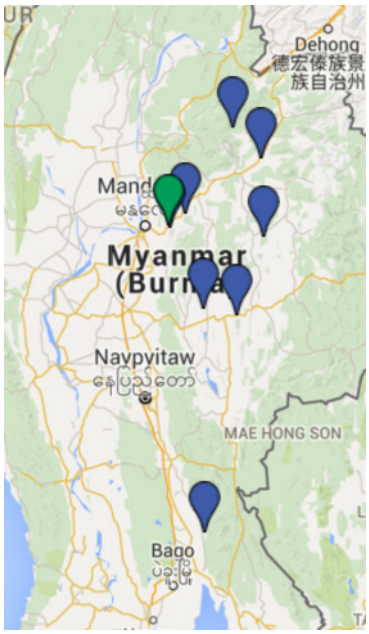
[25] Britannica Academia, Online ed., s.v., "Iron Processing." Accessed 15 January 2016. http://www.britannica.com/technology/iron-processing.

[26] Capacity data is limited to companies with published production data.

7.1.7 Locations of construction material in Myanmar

Locations of iron ore in Myanmar are shown in Figure 70. There are limited resources of iron ore in Myanmar; deposits can be found mostly within the north-central portion of the country near Mandalay. Raw materials are processed at a sponge iron plant in Mandalay that is managed by the Myanmar Ministry of Mines.

Figure 70. Locations of iron ore in Myanmar [green: plant, blue: deposit] (Google Maps, 2016).



7.2 Product

7.2.1 Reported quality

The scrap metal industry in Bangladesh divides the high and low quality metal resources from each other for use in different ways. High quality metal can be reused with little processing while low quality metal is recycled, melted, or rolled into rebar. This approach eliminates mixing of quality resources (Mizanur Rahman and Mayer 2015). Final products made using plain sheets are more durable than those made from raw iron, since international ships are made up of high-quality iron sheets (Hasan 2013).

7.3 Production factors

7.3.1 Raw material

Bangladesh does not have any production of steel based on iron ore. The major source of scrap metal material is from the shipbreaking industry.

Regarding ships and the shipbreaking industry, sea vessels or ships have a normal lifespan of around 30–40 years, after which repair and renovation are considered to be uneconomical. The retired ships are sold to commercial shipbreakers, which are currently centered in South Asia. The components of the ship are dismantled and recycled, depending on the resource. The shipbreaking industry itself may be considered as "green," because almost everything on the ship is recycled and reused (Sarraf et al. 2010). The components of material in an average shipbreaking are shown in Table 25.

Table 25. Percentage by weights and value of type of scraps recovered from average ship (Kusumaningdyah et al. 2013).

Type of resources	Weights in percentage	Value in percentage
Re-rollable ferrous scrap	30–35	25
Reusable metal sheets	40	40
Re-conditioned machinery	10–15	25
Re-melting scrap	3	2
Cable, stainless steel, Cu, brass	1	7
Furnace oil and oils, paints	2	0.50
Wooden and furniture	2	0.50
Burning, cutting losses and wastes	5–10	0

Scrap steel from shipbreaking represents up to 1.5 million MTPA. Total steel production is estimated at 2.2–2.5 million MTPA (Hasan 2013).

7.3.2 Technology

There are three main processes in shipbreaking: beaching, dry dock, and afloat/slipway. Beaching is the method most used in developed countries because it is nonmechanized. Dry dock is a more environmental-friendly option which occurs in developed countries because of the high capital investment required. Afloat/slipway is more difficult than dry dock; however, it is a more cost-effective option.

The beaching process is used in Bangladesh. Because of spring tides, ships can be displaced over mudflats and onto the beach. When ships do not make it over mudflats, they are pulled higher with chains or heavy steel-wire hawsers at the next tide to make them lighter.

Through the process of oxygen cutting, winches that drag the ship up the beach remove the steel from the exterior of the ship. These end-of-life ships are decomposed, and every part of the hull and machinery are recycled.

Iron materials are processed through multiple stages on site. The resources reused for final steel products represent up to 50% of the total metal resources of a ship. Low-quality or rusty scraps that are sold to re-rolling mills to produce rebar represent the other 50% of total metal resources. Non-iron materials are directly sold to end-users with minimal or no processing ("Ship Recycling" 2011).

8 Masonry

Masonry is the art and craft of building and fabricating with stone, clay, brick, or concrete block. The first use of masonry dates to prehistoric times, making it one of the oldest building materials in the world. It continues to be the most popular and leading construction material in developing regions. The choice of the material depends on geological formations and conditions in the area of interest. Masonry as a construction material is strong in compression and lacks tensile strength, therefore it is suitable for structural purposes such as walls, domes, vaults, and arches which are entirely under compression. Additional properties include sound insulation, fire resistance, and insulating against heavy temperature fluctuations. Architecturally, masonry is used for its color, scale, texture, pattern, and appearance of permanence.[27]

8.1 Industry

8.1.1 Global scenario

There are roughly 1.5 trillion bricks that are produced worldwide every year. A number of production technologies are used worldwide with vastly different emissions. For instance, China has the largest global annual output of approximately 800 billion bricks and has manufacturing that is dominated by modern technologies which produce lower emissions. The second-largest producer globally is India, which has an annual output of approximately 250 billion bricks and is also the largest artisanal producer of bricks. These artisanal kilns release greenhouse gases and other pollutants into the atmosphere and pose a health risk to brick workers and surrounding communities (Schmidt 2013).

8.1.2 Background

Bricks are an essential construction material in Bangladesh and have been popular for thousands of years. In a country like Bangladesh, clay soil is virtually the only natural raw material for construction, and so structures made of burnt bricks will dominate the built environment as well as the preferred construction material for the foreseeable future. Brick masonry also plays a significant role in the construction sector because natural

[27] Britannica Academia, Online ed., s.v., "Masonry." Accessed 15 January 2016. http://www.britannica.com/technology/masonry .

stones for aggregate are not readily available, and other building materials are costly (Ortlepp et al. 2015).

The brick sector in Bangladesh contributes around 1% to the country's GDP and provides employment to 750,000 people ("Financing Brick Kiln Efficiency" 2012). Currently, the demand for bricks is growing, and the brick sector is expected to grow annually by 2%–3% over the next decade due to housing and commercial development.

The kilns are large contributors to air quality pollution and poor community health in Dhaka, due to a lack of environmental regulation. This has resulted in between 530–5,000 premature deaths annually due to air pollution generated by brick kilns. However, the manufacturing process of using highly polluting kilns is not limited to Bangladesh: it is widespread throughout India, Nepal, Pakistan, China, Mexico (Luby et al. 2015; Darian et al. 2013).

8.1.3 Seasonality

Production of bricks occurs only during the dry season (from October to March), which means that kilns are only in operation for a total of six months because current technology does not allow for production during the monsoon. Floodwaters can easily wash away any unburned bricks in a monsoon season (Guttikunda et al. 2012). Because of dry season operation, construction of kilns is permitted on floodplain lands, or lands that flood during the annual rainy season in Bangladesh (Luby et al. 2015).

Brick kilns are not recognized as an industry in Bangladesh because year-round employment is not provided, and kilns do not have substantial fixed assets. The brick sector has remained underdeveloped from lack of financing. As a result, the kilns are not advancing technologically and have remained unchanged for years with inefficient energy consumption.

8.1.4 Producers

Many of the brickfields in Bangladesh are informal, small- to medium-sized businesses operating with outdated technologies, and they are severely polluting and have poor labor standards.[28] There are an estimated

[28] The only exception are fixed chimney kilns, which are almost entirely individually owned, with each owner possessing a single kiln. Having multiple ownership of one kiln and multiple kilns under the same ownership is rare.

5,000 brick kilns operating throughout Bangladesh, with approximately 1,000 surrounding Dhaka.[29]

During the typical year, there are around 17 billion bricks produced annually in Bangladesh ("Financing Brick Kiln Efficiency" 2012). It is estimated that the production rate is approximately 20,000 bricks per kiln per day for a half-year of operation. The primary workforce during this time period are agricultural laborers, who find less work during the dry season (Luby et al. 2015). There are around 200–300 daily workers per kiln on a seasonal basis (Corner 2014). Bricks produced in Bangladesh are traditionally manufactured for local consumption (Darian et al. 2013).

8.1.5 Consumers

According to kiln owners, there is a strong market demand for bricks fired in fixed-chimney kilns. Over 80% of a sample of interviewed kiln owners had sold out of the entire production inventory before the next season (Luby et al. 2015).[30] However, the brick industry has proven to be flexible in its response to changes in demand (Stulz 1992).

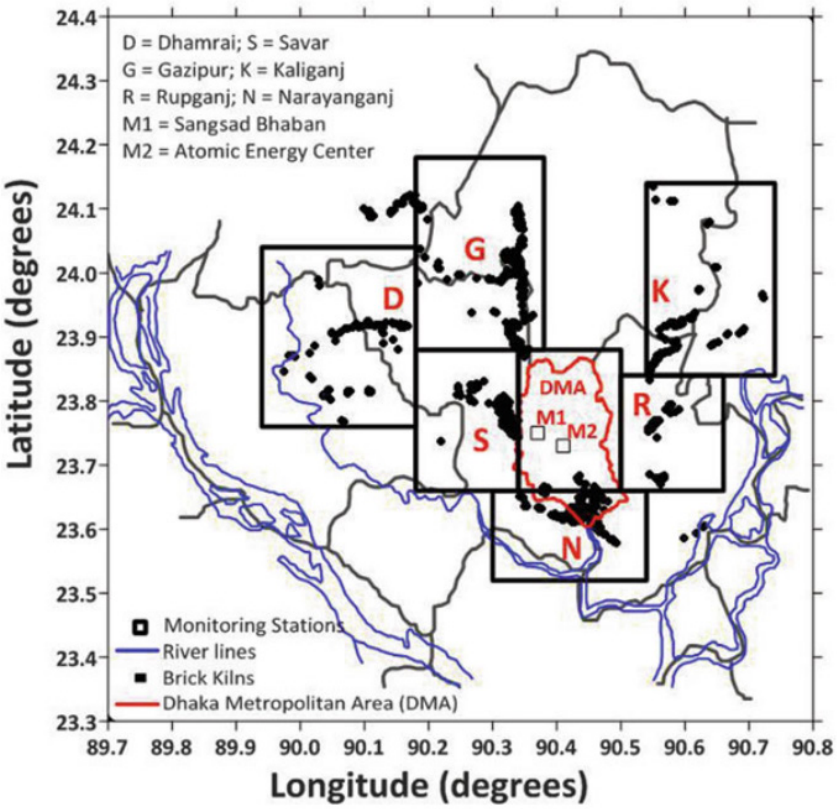
8.1.6 Locations of construction material

Brickfields are located near towns or major construction sites, with many of the sites used repeatedly over the years. Focusing on the Dhaka region, there are approximately 1,000 brick kilns spread across an area of 1,500 km^2, over the districts of Dhaka, Gazipur, Manikganj, and Narayanganj, as shown in Figure 71. Most of the kilns are located along intracity canals linking rivers, which also serve as arteries for raw material transport to the kilns and finished product distribution and delivery to construction sites (Corner 2014).

[29] The government authorities do not have the necessary resources to keep track of brickfields in Bangladesh. Many brickfields do not have a proper license to operate.

[30] The sample of interviewed brick kiln owners includes 15 in Dhaka and 5 in Jessore, Bangladesh.

Figure 71. Location of brick kilns within the Dhaka region (Corner 2014).



Within the Dhaka region, the largest cluster of kilns is Gazipur, which has around 320 kilns, and Narayanganj with 270 kilns. This is followed by Savar, Dhamrai in Dhaka, and Kaliganj in Gazipur, which each have over 100 kilns. Next is Rupganj in Narayanganj, with less than 100 kilns (Corner 2014).

Bricks are a regional project in Bangladesh in their production. The regional production of bricks is shown in Figure 72, and a heat map of the brick production is shown in Figure 73. Many brickfields are located within the Dhaka and Chittagong regions, in particular they are clustered in locations with floodplains. For instance in the Chittagong region, there are high concentrations of brick kilns in the Comilla and Chittagong districts because of the floodplain soils present in those locations (Hossain 2008).

Figure 72. Billions of bricks produced in Bangladesh per year in each division (Hossain 2008; Corner 2014).

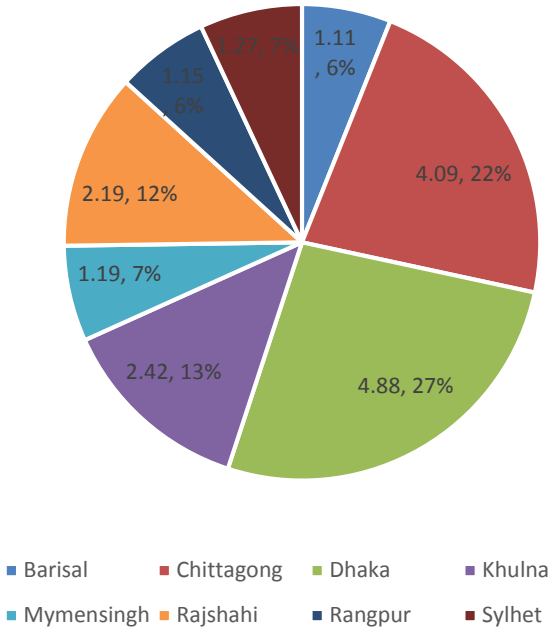
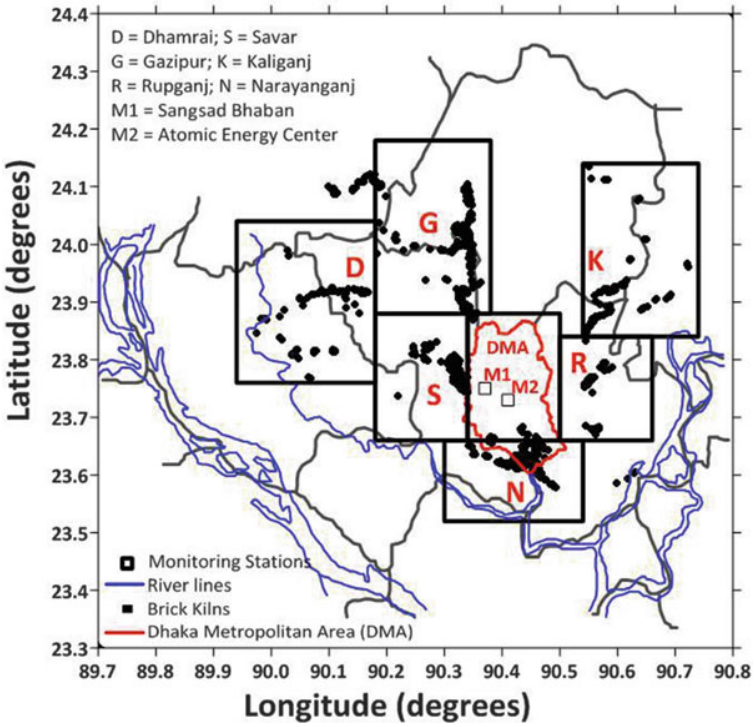


Figure 73. Map of brick kilns by region in Bangladesh (Corner 2014).



8.2 Product

8.2.1 Codes, methods, and standards

Masonry construction is covered in Part 5 Chapter 2.2 and Part 6 Chapter 7 of the BNBC (2014).

8.2.1.1 Clay and concrete masonry units

According to Section 7.2.2 BNBC-2014, there are four common types of masonry units which can be used in construction. Other types are listed in section 5.2.2.4.

- Common building clay bricks (BDS 208:1980)
- Burnt clay hollow bricks (BDS 1263:1990)
- Burnt clay facing bricks (BDS 1250: 1989)
- Hollow load-bearing concrete blocks (ASTM C90)

8.2.1.2 Mortar

According to Section 5.2.2.5 of BNBC-2014, mortar shall consist of a mixture of cementitious material and aggregates to which sufficient water and additives (if any) have been added. Mortar shall be one or more of the following: lime, masonry, cement, Portland cement, and mortar cement and shall conform to ASTM C270. The mix proportions of mortar are shown in Table 26.

Table 26. Mix proportion and strength of commonly used mortars (Table 6.7.1 in BNBC-2014).

Grade of Mortar	Mix Proportion by Volume 1,2		Minimum Compressive Strength at 28 days, N/mm2
	Cement	Sand	
M1	1	3	10
M2		4	7.5
M3		5	5
M4		6	3
M5		7	2
M6		8	1

1. Sand and cement shall be measured in loose volume and sand shall be well graded with a minimum F.M. of 1.2.
2. Lime to a maximum of $\frac{1}{4}$ th part by volume of cement may be used to increase workability.

8.2.1.3 Grout

According to Section 5.2.2.5 of BNBC-2014, grout shall consist of cementitious materials and aggregates to which water has been added. Grout shall be one or both of the following: lime and Portland cement, and the grout shall have a minimum compressive strength of 13 MPa. Grout used in reinforced and unreinforced masonry shall conform to ASTM C476.

8.2.1.4 Masonry wall thickness

The minimum design dimensions are provided in the code as well. For basic design requirements, the minimum thickness of load-bearing walls is 250 mm (10 in.), with the exception that stiffened bearing walls over 3 m (10 ft) in height may have a minimum effective thickness of 165 mm (6.5 in.) when gable construction is used. For parapet walls, the thickness must be at least 200 mm (8 in.), and the height shall be less than 4 times the thickness (BNBC 2014, 7.4.9.1).

For stiffening walls, the thickness shall be at least 100 mm (4 in.) for 1–3 stories and at least 200 mm (8 in.) for 4–5 stories (BNBC 7.4.4.1).

In seismic zone 4, the nominal thickness shall not be less than 150 mm (6 in.), with the exception of load-bearing reinforced hollow-clay units with a net area unit strength larger than 55 N/mm2, in which case the nominal thickness shall not be less than 100 mm (4 in.) (BNBC 2014, 7.8.5.4).

In high-wind regions, the minimum thickness for unreinforced grouted brick is 250 mm (10 in.); for reinforced exterior bearing wall and unreinforced hollow and solid masonry wall, the minimum thickness is 200 mm (8 in.); and for interior nonbearing walls, the minimum thickness is 150 mm (6 in.) (BNBC 2014, 7.9.6.1). For confined masonry, the minimum wall thickness should not be less than 100 mm (4 in.), and the wall height-to-thickness ratio should not exceed 30 (BNBC 2014, 7.11.8.12).

8.2.2 Construction material

There are several types of bricks on the market in Bangladesh, as listed in the subsections below (Luby et al. 2015).

8.2.2.1 Bangla bricks

The largest portion is Bangla bricks, which are bricks that are molded by hand and fired in a fixed-chimney kiln. There are four classifications assigned to Bangla bricks, based on how they are fired:

- *Grade A bricks* refer to bricks that are fired in the center of the kiln, thus thoroughly firing them. These bricks have the best strength and represent 50%–55% of bricks fired in a fixed-chimney kiln. This option costs $0.07 - $0.08 per brick in Bangladesh. This brick is suitable for construction of buildings, roads, and bridges.
- *Grade B bricks* are bricks that are fired above and below the optimal center firing zone of fixed-chimney kilns, and they represent approximately 10% of manufactured bricks. This grade of bricks is used in applications for structures requiring relatively less compressive strength and by purchasers to build outside boundary walls, foot paths, and courtyards. This option costs $0.05 - $0.06 per brick in Bangladesh.
- *Grade C bricks* are bricks that are of very poor quality and are generally used in temporary structures. It is typically purchased by low-income households for use as flooring in animal sheds or in the home. These bricks represent 5% of production.
- *Pickets* are bricks which are overly-fired in a kiln and are typically broken up into small pieces. These constitute 15%–20% of production and are typically a substitute for stones which are mostly unavailable in Bangladesh. The product is used as a base layer for nearly all paved roads in Bangladesh, and it is mixed with cement to form concrete for building construction. Pieces of fired brick comprise the most common coarse aggregate in concrete production. Brick aggregates produce concrete with a higher strength than concrete made with stone aggregate.

8.2.2.2 Auto bricks

Auto bricks are bricks that are machine molded and fired in a Hybrid Hoffman kiln. These bricks have a more consistent quality and shape, and they are typically purchased by builders of high-income neighborhoods and well-funded commercial buildings. These bricks typically cost $0.10 – $0.14 per brick in Bangladesh (Luby et al. 2015).

8.2.2.3 Ceramic bricks

Ceramic bricks are bricks that are the highest quality of bricks manufactured in Bangladesh. These are also produced by Hybrid Hoffman kilns. The bricks are machine molded, perforated with air spaces, exact in size, well fired, attractive, and have good strength. These bricks are used for architectural purposes. These bricks are the most costly option at $0.21–$0.24 per brick in Bangladesh (Luby et al. 2015).

8.2.2.4 Concrete bricks

Concrete bricks are not commonly made in Bangladesh. They are comparable to bricks in terms of service, but there exists consumer resistance in Bangladesh over the product. Using concrete block instead of brick increases the cost of the product because of the limited limestone resources, which is an essential raw material in cement production. The limestone deposits within Bangladesh are too deep to mine, which results in reliance on imported cement product (Luby et al. 2015). On the other hand, bricks use imported coal, which is a significantly smaller financial burden than cement bags (Hossain 2008). Some researchers suggest that using fly ash from thermal power plants to produce a different type of concrete brick (flyash brick) is a possible technical solution.

8.2.3 Quality standards

According to the Technical Specification for Buildings (2005), bricks shall be hard, sound, and give a clear metallic ring when struck with a small hammer or another brick. The brick shall be manufactured from clay, shale, or a combination of the two materials and shall be uniformly burnt. The brick shall not break when dropped from a height of 1.5 m (5 ft). The surface shall be too hard to scratch with a fingernail.

When testing brick quality, the salinity of the soil used in making the brick and the water absorption capacity of the bricks are of concern. The soil salinity of bricks can result in crystal formation on the brick surface. Water absorption capacity is determined through submerging the brick under water for 5–6 hours. If over 20% of the brick weight is absorbed in water, then the brick is considered to be low quality (Luby et al. 2015).

8.2.3.1 First-class bricks

First-class bricks shall be sound; hard and well burnt; free from cracks, nodules, and flaws; uniform in size, shape, and color; homogeneous in texture; and shall have plain rectangular faces with parallel sides and sharp, straight right-angled edges. The dimension of the brick shall be 240 mm x 115 mm x 70 mm, with a tolerance of ±3 mm. The maximum water absorption shall be 20% of the dry weight. The crushing strength shall not be less than 140 kg/cm2 and shall be 170 kg/cm2 on average. Lastly, the unit weight shall be 2,000 kg/m3.

8.2.3.2 Picked Jhama bricks

Picked Jhama bricks shall be over-burnt first-class bricks which have been uniformly vitrified, hard, and slightly black in color without cracks or spongy areas. The maximum water absorption shall not exceed 15%, and the crushing strength shall not be less than 170 kg/cm^2 and shall be 210 kg/cm^2 on average. All other requirements of first-class bricks shall apply.

8.2.3.3 First-class machine-made bricks

First-class machine-made bricks shall be thoroughly burnt and shall have plain regular faces with parallel sides and sharp, straight right-angled edges. The bricks shall be uniform in color, homogeneous in texture, and free from cracks, nodules, and flaws. The dimensions of the brick shall be 200 mm x 100 mm x 5 0mm, with a tolerance of ±5 mm. The maximum water absorption shall be 10% of the dry weight, and the crushing strength shall not be less than 210 kg/cm^2.

8.2.3.4 Clinker bricks

Clinker bricks shall be manufactured using a dry process, burnt at a higher temperature, and uniformly vitrified. The dimension of clinker bricks shall be 203 mm x 102 mm x 51 mm. The maximum water absorption shall be 12%–15% of the dry weight. The minimum compressive strength shall be 562 kg/cm2 and the modulus of rupture shall be at least 42 kg/cm^2.

8.2.4 Reported quality

According to a report done for the Army Corps of Engineers, bricks are not durable enough to withstand the violent storms of the monsoon season and the accompanying heavy floods (Porter 1991).

From a sampling of brick buyers in Bangladesh, there are reports that the same kiln owners have supplied bricks for several years, and that buyers have received a high-quality product at a fair price. The buyers were spared the need to visit the brick kiln and assess the quality with each purchase. When dealing with a new brickfield, they would visit the area regularly to assess the quality (Luby et al. 2015).[31]

8.3 Production factors

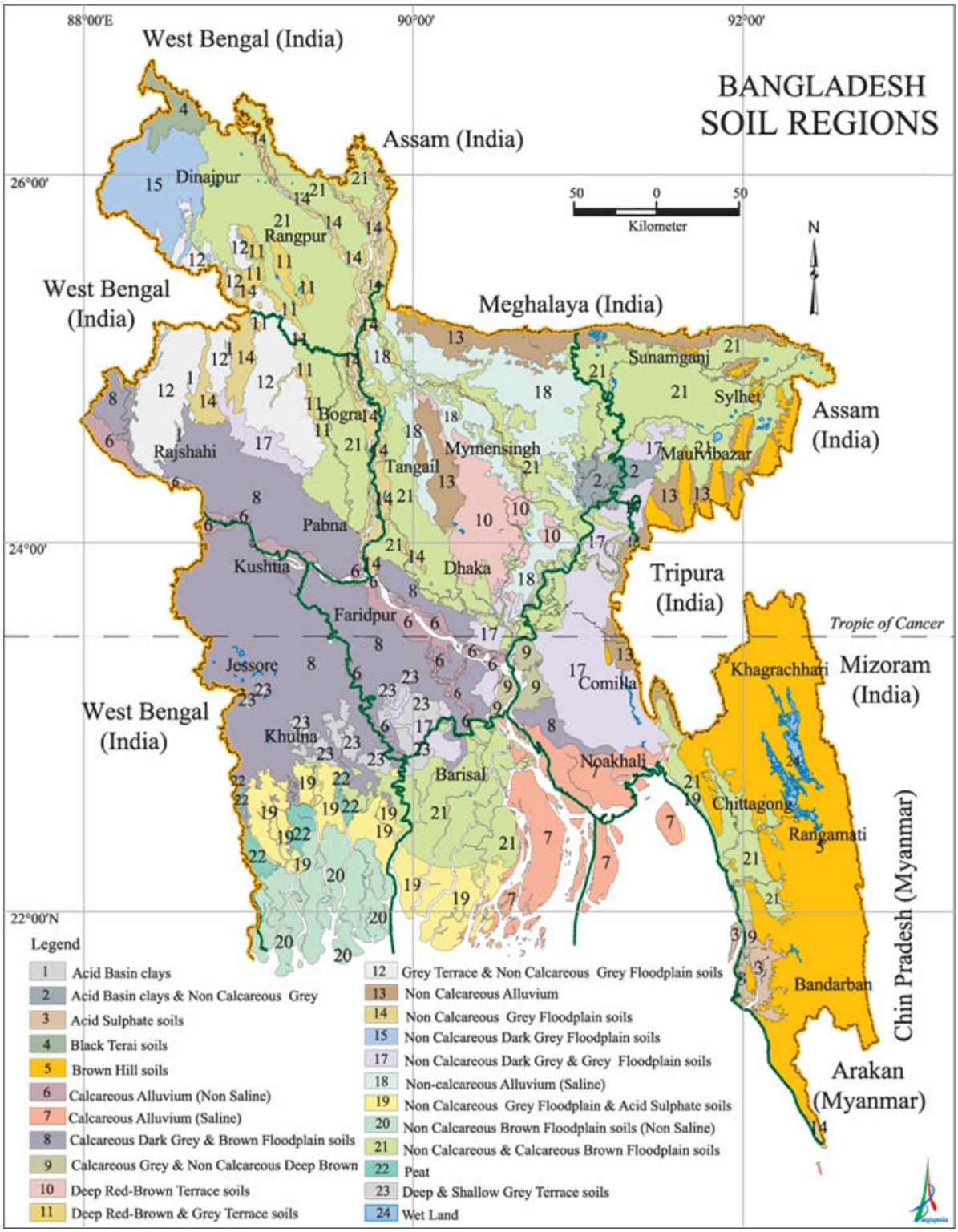
8.3.1 Raw materials

Clay used in brick production is usually mined from nearby brickfield sites because of the abundance of soil resources. Depending on the site conditions, suitable clay may be transported from distant locations.[32] From the geology of Bangladesh, there are different types of soils that can be used in brick making: alluvial soils, top soils, silty clay loam, and silty clay soils, which are shown in Figure 74. Topsoil is the most commonly exploited due to hand-mining techniques being prevalent throughout Bangladesh, which allow for easier and cheaper mining than other soil types. Deep soils require mechanical equipment, which is only available to large mining companies. From a building material point of view, clay should have as little organic matter as possible because this reduces the final strength of the brick, which makes topsoil a poor choice as a raw material in brick production (Ortlepp et al. 2015).

[31] Sampling of buyers consisted of buyers that purchase many bricks and included different types of buyers such as wholesalers, retailers, developers, and end-users. There were 27 buyers interviewed in Dhaka and 5 in Jessore, Bangladesh.

[32] Banglapedia. Online edition, s.v. "Brickfield". Accessed June 22, 2016. http://en.banglapedia.org/index.php?title=Brickfield,

Figure 74. Classification of soils in Bangladesh ("Banglapedia").[33]



[33] Banglapedia, s.v. "Bangladesh Soil." Accessed June 22, 2016.at: http://en.banglapedia.org/index.php?title=Bangladesh_Soil.

8.3.2 Imports and exports

Imports and exports of masonry are shown in Table 27. India is the largest source of clay imports for Bangladesh, followed by China, Japan, and Thailand. Additional imported clay resources originate from various countries in Europe and North America. A relatively small amount of clay is exported to India and the United Kingdom. Brick product is imported almost entirely from China, the producer of the largest number of bricks per year over any other country. However, brick produced in Bangladesh is exported to parts of Africa, Asia, Europe, and North America. The largest destination of exports are Italy and Singapore (Simoes 2013).

Table 27. Imports and exports of masonry, FY2013 (Simoes 2013).[34]

Imports and Exports of Masonry	Product		
Country	Brick	Clay	Grand Total
Export			
Africa	**$ 31,367**	**$ -**	**$ 31,367**
South Africa	$ 31,367	$ -	$ 31,367
Asia	**$ 80,776**	**$ 5,587**	**$ 86,363**
India	$ -	$ 5,587	$ 5,587
Singapore	$ 80,776	$ -	$ 80,776
Europe	**$ 341,160**	**$ 44,459**	**$ 385,619**
United Kingdom	$ 63,823	$ 44,459	$ 108,282
Netherlands	$ 10,959	$ -	$ 10,959
Germany	$ 9,305	$ -	$ 9,305
Italy	$ 257,073	$ -	$ 257,073
North America	**$ 10,870**	**$ -**	**$ 10,870**
United States	$ 10,870	$ -	$ 10,870
Import			
Asia	**$ 2,504,453**	**$ 4,678,077**	**$ 7,182,530**
India	$ 37,711	$ 1,760,515	$ 1,798,226
China	$ 2,466,742	$ 1,209,576	$ 3,676,318
Japan	$ -	$ 837,775	$ 837,775
Thailand	$ -	$ 765,728	$ 765,728
Singapore	$ -	$ 93,441	$ 93,441
Pakistan	$ -	$ 11,042	$ 11,042
Europe	**$ -**	**$ 107,167**	**$ 107,167**
Turkey	$ -	$ 56,852	$ 56,852
United Kingdom	$ -	$ 35,976	$ 35,976
Germany	$ -	$ 12,005	$ 12,005
Bulgaria	$ -	$ 2,334	$ 2,334
North America	**$ -**	**$ 632,541**	**$ 632,541**
United States	$ -	$ 632,541	$ 632,541

[34] Data is limited to general bricks made from the raw material of clay. Concrete has been omitted because the material has been covered in a previous section. The category of clay includes material used in construction and does not include fireclay, which is used for creating brick kilns.

8.3.3 Technology

Most of the brick production in Bangladesh is artisanal, meaning that bricks are shaped by hand. An artisanal kiln in Bangladesh requires a workforce of approximately 150 people to make four million bricks a year. During production, workers combine topsoil, manure, or other raw materials with water to form a thick slurry, which is then pressed into molds to be dried under the sun. The sun-dried "green" bricks are then fired in kilns and stacked on pallets for transport (Maral 2013).

There are a number of different kilns in operation in Bangladesh for artisanal brick production including Fixed Chimney Bull's Trench Kilns (FCBTKs), Zigzag Kilns, Vertical Shaft Brick Kilns (VSBKs), Hoffman Kilns, and Tunnel Kilns. The most common kilns are described in detail below.

8.3.3.1 Fixed chimney bull's trench kiln

The most common is a fixed chimney bull's trench kiln, which comprises 91% of all manufactured bricks in Bangladesh. The FCBTK is a retrofit of the original Bull's Trench kiln design, which was banned in Bangladesh due to its draft and high emissions. Many of the Bull's Trench kilns in Bangladesh were outfitted with a fixed chimney, which results in lower levels of pollution and, as a result, lower environmental and health impacts. However, the kiln is still very environmentally hazardous.

Most brick manufacturers prefer this method over other kiln options because of the low capital costs. The knowledge of FCBTK construction and operation is widespread, and the only skilled position for operation is the fireman who adds coal and/or firewood to the kiln, and this experience is widely available. Fixed-chimney kilns use firewood to start the fire at the beginning of the season, and they use coal as a fuel source through the majority of the season. However, some kiln owners report using both firewood and coal (Luby et al. 2015).[35]

[35] Data originates from a survey of 15 brick kiln owners in Dhaka and 5 in Jessore, Bangladesh. The sample consists of recommended owners from officials from the Bangladesh Brick Manufacturing Owners Association (BBMOA) and their additional contacts.

8.3.3.2 Hoffman kiln

The second-most common kiln is a Hoffman kiln, and this type of kiln produces 5% of the manufactured bricks in Bangladesh. The Hoffman kiln has a fixed roof that allows for high energy efficiency and for operation during the rainy season if the operator has sufficient land for storing unfired bricks. The Hoffman kiln is built of low thermal-conductivity firebricks. Most of the Hoffman kilns in Bangladesh use coal as an energy source; on a global scale, electricity and natural gas are used more typically (Luby et al. 2015).

8.3.3.3 Hybrid Hoffman kiln

A hybrid Hoffman kiln is a version of the Hoffman kiln that improves heat retention and captures waste heat for recirculation in the drying tunnel. The consumption of coal is reduced by allowing for pulverized coal to enter the wet clay in each brick, which bakes the brick from the inside. Compared to the Hoffman kiln, this is a lower-cost option that has thinner walls, is built of regular bricks, and has no cover over the kiln. The production capacity is a minimum of 50,000 bricks per day per kiln or 15 million bricks per year ("Project Design Document" 2014).

8.3.3.4 Zigzag kiln

The zigzag kiln accounts for 1% of the bricks manufactured in Bangladesh. Despite their limited use, the Government of Bangladesh has promoted this kiln option as an alternative to fixed-chimney kilns. Airflow in the kiln is directed with a zigzag arrangement of bricks, and a draft fan moves the heated air more thoroughly through the bricks. The design, construction, and operation of zigzag kilns determine the efficiency of the kiln (Maral 2013).

Zigzag kilns have a higher initial cost, and fewer people know how to construct them. Operation of zigzag kilns requires more laborers with training, which increases operational costs (Luby et al. 2015). The operation procedure is more sophisticated than for an FCBTK and, as a result, poor operation has the same energy consumption and pollution effe (Hossain 2008). However with suitable operation, the zigzag kiln offers an alternative to the more expensive Hoffman and tunnel kilns (Maral 2013).

8.3.4 Power

The brick-making industry is highly energy intensive, with energy accounting for around 50% of production costs. There are a number of ways to improve energy usage, such as increasing the number of bricks fired at a time, improving the temperature control through the chimney system, introducing a higher-draft kiln (Stulz 1992). Brick kilns do not rely on the electricity grid for power, but rather they use a number of other power sources such as coal, natural gas, wood, and electricity generators.

A fixed-chimney kiln, the most common kiln in Bangladesh, does not require electricity, and therefore does not face a loss of productivity when electricity is not available. Both a fixed-chimney kiln and a Hoffman kiln rely on coal for energy consumption. Zigzag kilns require an electrical fan for operation. Because electricity is unavailable in many locations and does not run continuously when available, kiln owners require a diesel-powered electricity generator (Luby et al. 2015).

9 Construction Material Database

9.1 Purpose

A database of construction materials is a collection of information that identifies a site, the geographic location, and the characteristics of that site. The information on materials in the production of aggregate, cement, concrete, brick, steel, and lumber for Bangladesh are to be implemented into a geodatabase to more easily picture, analyze, and comprehend patterns and relationships.

9.2 Categories

Each entry within the database is given 18 fields, which may be a string or a number variable type.

9.2.1 Site identification

- *Company*: additional information about the name of the company that is most currently operating at the particular location will be included in case there are operations occurring at the site.
- *Site Name*: identifies the site by a title, which represents the name of the operation or deposit at the location. For instance, specific titles or descriptions of production facilities and corporate offices will be included.

9.2.2 Geographic location

- *Country*: the name of the country in which the site is located.
- *City*: a more in-depth political state, province, or territory within the country that the construction resource is located in.
- *Latitude*: geographic latitude of the site represented in decimal degrees and WGS84 Web Mercator projection.
- *Longitude*: geographic longitude of the site represented in decimal degrees and WGS84 Web Mercator projection.
- *Precision*: the preciseness of the latitude-longitude location. This is defined by the following characters:
    - S: the latitude-longitude coordinate pair that represents the exact site location

- A: an approximate location of an individual site provided as a latitude-longitude coordinate pair, which may be represented by a region or city if limited information is available.
- C: a cluster of sites to represent the characteristics of a region or city, represented as latitude-longitude coordinate pair.

9.2.3 Site characteristics

- *Construction resource*: the commodity produced at the site, such as a deposit or resource, regardless of operation.
- *Product*: the specific type of commodity produced at the site.
- *Industry type*: the type of operations occurring at the site including the following three categories:
  - *Seasonal:* variations exist in the production and/or consumption of the material based on the season.
  - *Cyclical:* variations exist in the production and/or consumption of the material based on business cycles.
  - *Regular:* no variations occur due to the aforementioned industry behavior effects.
- Site type: the type of operation most currently existing at the site; these include four different categories:
  - *Office*: corporate offices locations, which are an important part in the control and operations of processing. This category omits offices specifically for sales.
  - *Plant*: plants, factories, and other manufacturing sites: where raw materials are transformed into the final product.
  - *Terminal:* terminals and shipping ports: where the product is stored for future distribution as well as where the product is imported or exported
  - *Deposit*: mines, natural resource and other raw material deposits: which is where raw materials are extracted or available for excavation.
- *Capacity*: the amount of a commodity that is possible to produce at the plant for a given construction resource. This number does not reflect the actual capacity, but is rather based on what is installed on site.
- *Units*: the unit of measurement for the facility's capacity, if a capacity is provided.
- *Employees*: the exact or approximate number of workers at the site.
- *Quality*: the grade of the product prepared at the plant.

- *Electric requirements*: the electric power used by the plant, represented in megawatts. Power may originate on-site or from the national grid.
- *Import*: the source of imported materials to produce commodities, if imported.
- *Notes*: any additional and pertinent information about the site.

10 Conclusions

Because construction of military facilities is one of the most important aspects of military missions, this effort developed a GIS-based decision support tool to assist in siting FOBs in theater. As a case study, the availability of locally sourced materials and their suitability for supporting the military mission were analyzed for the Dhaka, Bangladesh region. The methodology took into account 15 different variables in the process. The key factors included in the analysis and determination of materials and location included local materials accessibility, quality and quantity, local transportation infrastructure, and population densities. This case study is unique due to Bangladesh's high flood-risk level, and special care was taken to account for this factor. The effective proximity factor also allowed for the central locations of each construction resource within the respective regions to be determined and tied to each other. It was determined that brick is the most widely used and trusted construction material in the region.

Overall, this case study serves as an example of creating a materials database and methodology for a megacity. While every region has a unique methodology, each can be adapted from this case study.

References

Altrell, Dan, Mohamed Saket, Leif Lyckeback, and Marco Piazza, ed. 2007. National Forest and Tree Resources Assessment 2005–2007, Bangladesh. Report for Forest Department, Government of the People's Republic of Bangladesh.

"Bangladesh." 2011. Map in The World Factbook (online edition). Central Intelligence Agency (CIA).

"Bangladesh Transportation." 2011. Map in The World Factbook (online edition). Central Intelligence Agency (CIA).

Basak, Shukla R., Anil C. Basak, and Mohammed A. Rahman. 2015 "Impacts of Floods on Forest Trees and Their Coping Strategies in Bangladesh." *Weather and Climate Extremes* 7: 43–48.

BNBC. 2014. "Bangladesh National Building Code 2014." Ministry of Housing and Public Works.

BNBC. 2015. "Bangladesh National Building Code 2015." Ministry of Housing and Public Works.

"Cement Industry in India." 2016. India Brand Equity Foundation http://www.ibef.org/industry/cement-india.aspx.

"Cement Production India." 2014. Euromoney Institutional Investor Company.

Choudhury, Junaid K. "National Forest Policy Review - Bangladesh." Accessed 27 June, 2016. https://www.scribd.com/doc/27047634/national-forest-policy-review-bangladesh.

Corner, Robert. 2014. Dhaka Megacity: Geospatial Perspectives on Urbanisation, Environment, and Health. Technical paper. Edited by Ashraf Dewan. Dordrecht: Springer.

Darain, K. M., A.B. M.S. Rahman, A. Ahsan, A.B. M.S. Islam, and B. Yusuf. 2013. "Brick Manufacturing Practice in Bangladesh: A Review of Energy Efficacy and Air Pollution Scenarios." *Journal of Hydrology and Environment Research* 1(1): 60–69. http://jher.org/wp-content/uploads/2013/10/Darain-et-al.pdf.

de Vries, Shila K. 2002. "Bamboo Construction Technology for Housing in Bangladesh Opportunities and Constraints of Applying Latin American Bamboo Construction Technologies for Housing in Selected Rural Villages of the Chittagong Hill Tracts, Bangladesh." Eindhoven: Technische Universiteit Eindhoven.

"Digital Chart of the World." 1993. U.S. Defense Mapping Agency. Environmental Systems Research Institute, GeoCommunity. Accessed 10 January 2016.

"Feasibility of a Wood Seasoning Plant for the Mirpur Furniture Cluster". 2005. Katalyst, Small & Medium Enterprise Foundation, Ministry of Industries, Government of the People's Republic of Bangladesh. http://www.smef.org.bd/functions/dl_file.php?id=1&file=../media/dvp/KATALYST_on_MirpurFurniturePlant.pdf.

FEMA 310. 1998. *Handbook for the Seismic Evaluation of Buildings – A Prestandard*. American Society of Civil Engineers.

Fernholz, Kathryn, and Florian Kraxner. 2012. "Certified Forest Products Markets, 2011–2012." Chapter 10, p 107–116 in *UNECE/FAO Forest Products Annual Market Review, 2011-2012*.

"Financing Brick Kiln Efficiency Improvement Project." 2012. Report for ADB Project 45273-001 in Bangladesh. Asian Development Bank.

Fong-Sam, Yolanda. 2014. "The Mineral Industry of Bangladesh." In *2012 Minerals Yearbook - Bangladesh* [Advance Release], p 4.1–4.5. Washington, DC: U.S. Department of the Interior, U.S. Geological Survey.

Ghosh, Bose & Associates Pvt Ltd. 2013. "Chaper 1: Introduction and Chapter 4: The Project." In *EIA* [environmental impact assessment] *Study of Shale Mine at Shella*. Prepared for Lum Mawshun Minerals Pvt. Ltd.

Govil, Kailash. 2000. *Forest Resources of Bangladesh: Country Report*. Rome: Forestry Department, Food and Agriculture Organization of the United Nations.

Guttikunda, Sarath K., Bilkis A. Begum, and Zia Wadud. 2012. "Particulate Pollution from Brick Kiln Clusters in the Greater Dhaka Region, Bangladesh." *Air Quality,Atmosphere & Health* 6 (2): 357–365.

Haq, Nazmul, Saidur Rahman Chowdhury, and Hunain Mahmud. 2013."A Brief Study of Ready-Mix Concrete: Features and Uses in Construction on the Context of Bangladesh." IOSR *Journal of Mechanical and Civil Engineering* 8(3): 55–57.

Harun, Zubaidah, Pakhriazad Hassan Zaki, Mohd Hasmadi Ismail, and Mohd Khairil Wahidin Awang. 2014. "Trend of Timber Products Export in Malaysia." International Conference on Business, Management, and Corporate Social Responsibility, held February 14–15 in Batam, Indonesia.

Hasan, Mehedi. 2013. "Steelmakers of Bangladesh: Forging Ahead Amid Overcapacity." *IDLC Monthly Business Review* 9(3): 7-11. Accessed 23 December 2015: http://dx.doi.org/10.15242/ICEHM.ED0214025.

Hettwer, Mike. 2014. A Maritime Graveyard. The Ship Breakers Photo Gallery, National Geographic, Chittagong. http://ngm.nationalgeographic.com/2014/05/shipbreakers/hettwer-photography.

"Homestead Bamboo Plantations, Bangladesh." 2005. TECA: Technologies and Practices for Small Agricultural Producers. October 23, 2005. Accessed February 4, 2016.

Hossain, Ijaz. 2008. "Impact of Brick Kiln Pollution on Dhaka City." Presentation at Bangladesh University of Engineering and Technology, 17 April 2008. Accessed 10 April 2016.

Hossain, M. K. 2003. "Growth Performance and Critics of Exotics in the Plantation Forestry of Bangladesh." Paper 0113-B1 submitted to the XII Word Forestry Congress held in Quebec City, Canada.

Hossain, Tanvir, Md. Abdus Salam, and Mohiuddin A. Kader. 2011. "Previous Concrete Using Brick Chips as Coarse Aggregate: An Experimental Study." *Journal of Civil Engineering* 40(2): 125–137.

Hossain, Yasin. 2015. "Bangladesh's Cement Industry: Thriving After Years of Restructuring." *LDLC Monthly Business Review* 11(3): 5–13

Indian Minerals Yearbook 2012 (Part-I: General Reviews). 2014. Government of India Ministry of Mines.

Islam, F.A. Samiul, Mehdi Iftekharul Alam, and Shisir Barua. 2016. "Investigation on the Uses of Steel as a Sustainable Construction Material in Bangladesh." *International Journal of Scientific Engineering and Applied Scienc*e 2(1) 41–52.

Islam, Moinul, Sailfullah Muhammad, Mohammad Mozalfar Hossain, Abdullah Al Mamun, Igram Uddin Al Amran, Mohammad Abdul Kader, and Nirab Biswas. 2013. "Time Consumption Analysis of Private Sector Sawmill in Bogra." *Bangladesh Research Publications Journal* 9(1): 57–63.

IS 848. 2006. "Specification for Synthetic Resin Adhesives for Plywood (Phenolic and Aminoplastic)" [CED 20: Wood and Other Lignocellulosic Products]. New Delhi: Bureau of Indian Standards.

IS 5539. 1969. "Specification for Preservative Treated Plywood" [CED 20: Wood and Other Lignocellulosic Products]. New Delhi: Bureau of Indian Standards.

IUCN Red List of Threatened Species. International Union for Conservation of Nature. Accessed 08 March 2016: http://www.iucnredlist.org/.

Jahid, Jayedul Islam. 2016 (accessed). "Ready Mix Concrete." Paper online at https://www.academia.edu/7358681/Ready_mix_concrete.

Koehn, Enno, and Mohsin Ahmmed. 2001. "Quality of Building Construction Materials (Cement) In Developing Countries." *Journal of Architectural Engineering* 7(2): 44–50. Accessed 18 January 2016.

Kusumaningdyah, Widha, Agustina Eunike, and Rahmi Yuniarti. 2013. "Modeling Tradeoff in Ship Breaking Industry considering Sustainability Aspects: A System Dynamics Approach." Presented at 3rd International Conference on Sustainable Future for Human Security, SUSTAIN 2012, held 3-5 November 2012 at Clock Tower Centennial Hall, Kyoto University, Japan. In *Procedia Environmental Services* Vol. 17: 785–794.

Lebow, Stan. 2007. "Preservative Treatments for Building Components." Presented at Wood Protection 2006 held 21–23 March 2006 in New Orleans, Louisiana. Published in conference proceedings. Madison, WI : Forest Products Society. ISBN: 1892529483: p 57–64.

Luby, Stephen P., Debashish Biswas, Emily S. Gurley, and Ijaz Hossain. 2015. "Why Highly Polluting Methods are Used to Manufacture Bricks in Bangladesh." *Energy for Sustainable Development* 28: 68–74.

McNulty, William E. "Flood Zones." 2009a. Map in Government of Bangladesh. Oak Ridge National Laboratory Landscan. 2009b. Accessed 25 April 2016.

McNulty, William E. 2009b. “Population Map.” In Government of Bangladesh. Oak Ridge National Laboratory Landscan. Accessed 25 April 2016.

Mizanur Rahman, S. M., and Audrey L. Mayer. 2015. “How Social Ties Influence Metal Resource Flows in the Bangladesh Ship Recycling Industry.” *Resources, Conservation and Recycling* 104(Part A): 254–264.

Mohammed, T., A. Hasnat, M. Awal, M., and S. Bosunia. 2014. “Recycling of Brick Aggregate Concrete as Coarse Aggregate.” *Journal of Materials in Civil Engineering* 27(7). doi: 10.1061/(ASCE)MT.1943-5533.0001043, B4014005.

Nahar, Zebun. 2011. “Research Report: Cement Sector of Bangladesh.” IDLC Finance.

“NAMA Proposal for the Steel Sector in Bangladesh.” 2014. NDF: Nordic Development Fund, Ministry of Foreign Affairs of Denmark, Embassy of Denmark at Dhaka.

Ortlepp, Regine, Georg Schiller, and Zita Sebesvari. 2015. “Building Material Substitutes vs. Topsoil Harvesting - Technical Considerations with a Focus on Developing Countries.” In *Proceedings of the Smart and Sustainable Built Environment (SASBE) Conference 2015*.

Phadke, Abhijit. 2013. “Adhesives Used for Making Plywood.” Positive Indians Blog. Accessed 19 February 2016: http://blog.positiveindians.in/plywood/adhesives-for-plywood.html.

Population and Housing Census-2011, Vol. 2. 2014. Bangladesh Bureau of Statistics: Statistics and Informatics Division Ministry of Planning. http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/National%20Reports/Union%20Statistics.pdf .

“Population density people per sq. km of land area.” 2016. World Bank. Accessed 27 June 2016. http://data.worldbank.org/indicator/EN.POP.DNST.

Porter, Kevin S. 1991. "Building to Last in the Tropics." *Engineer* 21(1):: 36-39. Accessed 16 November 2015.

Project Design Document Form for Small-Scale Project Activities. 2014. Form F-CDM-SSC-PDD. United Nationals Framework Convention on Climate Change/Convention-Cadre des Nations Unies sur les Changements Climatiques.

Rabbi, Fazle, Mahmudul Islam, and Mizanur Rahman. 2015. “Wood Preservation: Improvement of Mechanical Properties by Vacuum Pressure Process.” *International Journal of Engineering and Applied Sciences* Vol. 2 (4): 75–79.

Rahman, Mohammad Mahfuzur. 2012. “Analyzing the Contributing Factors of Timber Demand in Bangladesh.” *Forestry Policy and Economics*, 25: 42–46. Accessed 30 January 2016 (ScienceDirect). doi: 10.1016/j.forpol.2012.08.006.

Sarraf, Maria, Frank Stuer-Lauridsen, Milen Dyoulgerov, Robin Bloch, Susan Wingfield, and Roy Watkinson. 2010. “Ship Breaking and Recycling Industry in Bangladesh and Pakistan.” Report No. 58275-SAS, World Bank.

Saunders, Amy. 2015. "The Cement Industries of Southeast Asia." *Global Cement Magazine*, 14 April. Accessed 5 November 2015: http://www.globalcement.com/magazine/articles/922-the-cement-industries-of-southeast-asia.

Schmidt, Charles W. 2013. "Modernizing Artisanal Brick Kilns a Global Need." *Environmental Health Perspectives* 121(8): A242–A249. http://ehp.niehs.nih.gov/121-a242/.

Scurlock, J.M.O., D.C. Dayton, and B. Hames. 2000. "Bamboo: An Overlooked Biomass Resource?" *Biomass and Bioenergy*19(4): 229-244. Accessed 19 February 2016 (Elsevier).

"Ship Recycling: Practice and Regulation Today." 2011. London: Lloyd's Register: Life Matters.

Simoes, Alexander J.G. 2013. "The Observatory of Economic Complexity." http://atlas.media.mit.edu/en/

Simoes, Alexander J.G., and Cesar A. Hidalgo. 2011. "The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development." Paper (WS-11-17) in Papers from the 2011 AAAI Workshop from the Twenty-Fifth AAAI Conference on Artificial Intelligence: Integration of Analytics and Visualization.

"Steel Industry of India." 2016. India Brand Equity Foundation. Accessed 11 March 2016. http://www.ibef.org/industry/steel.aspx.

Stouter, Patti. 2008. "Shaping Buildings for the Humid Tropics: Cultures, Climate, and Materials." Member of American Society of Landscape Architects blog post. Accessed 16 November 2015: http://blog.greenhomebuilding.com/2008/11/shaping-buildings-for-humid-tropics.htm..

Stulz, Roland, and Karl Wehrle. 1992. "Sector Study on Building Materials in Bangladesh." *Building Advisory Service and Information Network News*, No. 3. The New Zealand Digital Library: http://www.nzdl.org/gsdlmod?e=d-00000-00---off-0cdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-00&cl=CL1.25&d=HASH7b89671556d53b26cba6bc.3&gt=1 .The University of Waikato. Accessed 16 November 2015.

Syverson, Chad. 2008. "Markets: Ready-Mixed Concrete." *Journal of Economic Perspectives* 22(1): 217-234.

Tariq, Saiful Hasan, and Mahbuba Afroz Jinia. 2012. "Study on Rural Built Forms in Narayanganj, Bangladesh in the Context of Using Building Materials for Thermal Comfort." *Stamford Journal of Environment and Human Habitat*. Accessed 16 November 2015. Vol 1: 73–86. https://www.academia.edu/3650819/Study_on_Rural_Built_Forms_in_Narayanganj_Bangladesh_in_the_Context_of_Using_Building_Materials_for_Thermal_Comfort

"Technical Specifications for Buildings." 2005. Government of the People's Republic of Bangladesh: 76–106.

Uddin, Mohammed Tarek, Ariful Hasnat, Nafis Sarwar, H.K. Das, J.M. Miah, and M.A. Awal. 2013. "Sustainable Development of Concrete Construction Works in Bangladesh: Key Issues." Paper for Third International Conference on Sustainable Construction Material and Technology. University of Asia Pacific, Bangladesh. Accessed 15 November 2015. doi: 10.13140/2.1.4541.7286.

Wee, T. H., and S. C. Lee. 1996. "Crushed Bricks As Coarse Aggregate For Concrete." In *Concrete in the Service of Mankind: Concrete for Environmental Enhancement and Protection* by Ravindra Dhir and Thomas Dyer. 1st ed. Suffolk: St Edmundsbury, 505–514.

"Wood Based Panel Markets in the World to 2019 - Market Size, Development, and Forecasts." 2015. Global Research & Data Services.

Appendix: Population Data and Construction Materials Database

The material provided in this appendix adds data for how the methodology was created in regards to the population of various cities. Along with this, the Construction Materials Database is provided as a reference for the reader.

Table A1 provides a breakdown of the population and density for each of the eight regions within Bangladesh.

Table A1. Population by division and respective cities with 100,000 or more people (Population and Housing Census-2011, 2014).

Division and City	Population (2011)	Density (people per sq. km)
Barisal Division	**8,325,666**	**626.1**
Barisal	328,278	16,422.1
Chittagong Division	**28,423,019**	**841.6**
Chittagong	2,592,439	15,351.7
Comilla	326,386	28,455.6
Brahmanbaria	172,017	9,784.8
Cox's Bazar	167,477	24,449.2
Chandpur	159,021	15,016.1
Feni	156,971	5,771
Noakhali	107,654	6,779.2
Dhaka Division	**36,054,418**	**1,772.8**
Dhaka	7,033,075	45,716.8
Narayanganj	543,090	42,796.7
Tongi	476,350	15,292.1
Savar	286,008	7,526.5
Gazipur	213,061	4,587.9
Rupganj	200,177	--
Nawabganj	180,731	5,261.5
Tangail	167,412	5,688.5
Kadamrasul	166,291	13,313.9
Kaliakhair	157,162	--
Narsingdi	146,115	15,986.3
Faridpur	121,632	5,370.1
Bhairab Bazar	118,992	7,569.5
Kishoreganj	103,798	4,101.1

Division and City	Population (2011)	Density (people per sq. km)
Khulna Division	**15,687,759**	**704.4**
Khulna	1,063,342	9,462.8
Jessore	201,796	13,709
Satkhira	113,322	3,109
Jhenida	107,834	2,721.7
Kushtia	102,998	7,731.8
Mymensingh Division	**11,370,000**	**1,039.9**
Mymensingh	258,040	11,874.8
Jamalpur	142,764	2,679.5
Rajshahi Division	**18,484,858**	**1,015.8**
Rajshahi	449,756	4,628.1
Bogra	350,397	32,686.3
Sirajganj	158,913	5,577.9
Naogaon	150,549	4,065.6
Pabna	144,442	5,304.5
Rangpur Division	**15,787,758**	**967.6**
Rangpur	294,268	5,805.2
Dinajpur	186,727	9,710.2
Saidpur	123,712	3,586.9
Sylhet Division	**9,910,219**	**12,596**
Sylhet	479,837	18,107.1
Sripur	126,249	--

Tables A2–A22 provide the construction materials database, by material, for the region of Dhaka, Bangladesh. Refer to Section 9.2 for more information about each column. Some cells in some of the tables have no information (blank) due to lack of availability of information and/or lack of validation of information.

Table A2. Materials database – Bangladesh– masonry (ERDC-CERL).

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Barisal	22.156547	90.094176	C	Seasonal	BORGUNA REGION KILN CLUSTER	PLANT	44
Barisal	22.356264	90.328641	C	Seasonal	POTUAKHALI REGION KILN CLUSTER	PLANT	79
Barisal	22.320404	90.738608	C	Seasonal	BHOLA REGION KILN CLUSTER	PLANT	75
Barisal	22.621895	90.010194	C	Seasonal	PIROJPUR REGION KILN CLUSTER	PLANT	154
Barisal	22.585165	90.187905	C	Seasonal	JHALOKATHI REGION KILN CLUSTER	PLANT	88
Barisal	23.240573	90.500946	C	Seasonal	SHAKHIPUR REGION KILN CLUSTER	PLANT	66
Barisal	22.704327	90.345221	C	Seasonal	BARISAL REGION KILN CLUSTER	PLANT	600
Chittagong	23.975253	91.112933	C	Seasonal	BRAHMANBARIA REGION KILN CLUSTER	PLANT	291
Chittagong	23.459002	91.184312	C	Seasonal	COMILLA REGION KILN CLUSTER	PLANT	595
Chittagong	23.277327	90.770896	C	Seasonal	CHANDPUR REGION KILN CLUSTER	PLANT	300
Chittagong	22.944524	90.825945	C	Seasonal	LAXMIRPUR REGION KILN CLUSTER	PLANT	331
Chittagong	22.781978	91.119548	C	Seasonal	NOAXHALI REGION KILN CLUSTER	PLANT	322
Chittagong	22.981493	91.425972	C	Seasonal	FENI REGION KILN CLUSTER	PLANT	419
Chittagong	22.62	91.733635	C	Seasonal	CHITTAGONG REGION KILN CLUSTER	PLANT	1314

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Chittagong	23.120243	91.94491	C	Seasonal	KHAGRACHHARI REGION KILN CLUSTER	PLANT	123
Chittagong	22.726606	92.295028	C	Seasonal	RANGAMATI REGION KILN CLUSTER	PLANT	62
Chittagong	21.223254	92.071232	C	Seasonal	COX'S BAZAR REGION KILN CLUSTER	PLANT	256
Chittagong	21.822879	92.372451	C	Seasonal	BANDARBAN REGION KILN CLUSTER	PLANT	75
Dhaka	24	90.335	C	Seasonal	GAZIPUR REGION KILN CLUSTER	PLANT	1168
Dhaka	23.641901	90.463802	C	Seasonal	NARAYANGANJ REGION KILN CLUSTER	PLANT	986
Dhaka	23.797268	90.313717	C	Seasonal	SAVAR REGION KILN CLUSTER	PLANT	438
Dhaka	23.91831	90.10207	C	Seasonal	DHAMRAI REGION KILN CLUSTER	PLANT	292
Dhaka	23.891588	90.582791	C	Seasonal	KALIGANJ REGION KILN CLUSTER	PLANT	329
Dhaka	23.78	90.57873	C	Seasonal	RUPGANJ REGION KILN CLUSTER	PLANT	183
Dhaka	23.071007	89.881921	C	Seasonal	GOPALGONJ REGION KILN CLUSTER	PLANT	123
Dhaka	23.485371	89.816224	C	Seasonal	FARIDPUR REGION KILN CLUSTER	PLANT	309
Dhaka	23.216571	90.158232	C	Seasonal	MADARIPUR REGION KILN CLUSTER	PLANT	97
Dhaka	24.027028	90.778479	C	Seasonal	NARSINGHDI REGION KILN CLUSTER	PLANT	203
Dhaka	23.527414	90.415875	C	Seasonal	MUNSHIGANJ REGION KILN CLUSTER	PLANT	225
Dhaka	23.86	89.943893	C	Seasonal	MANKIGANJ REGION KILN CLUSTER	PLANT	525
Dhaka	24.31	89.974665	C	Seasonal	TANGAIL REGION KILN CLUSTER	PLANT	361
Khulna	23.913671	88.98259	C	Seasonal	KUSHTIA REGION KILN CLUSTER	PLANT	132
Khulna	23.782558	88.694286	C	Seasonal	MEHERPUR REGION KILN CLUSTER	PLANT	119

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Khulna	23.486405	89.426207	C	Seasonal	MAGURA REGION KILN CLUSTER	PLANT	71
Khulna	23.127678	89.566905	C	Seasonal	NARAIL REGION KILN CLUSTER	PLANT	335
Khulna	23.651691	88.836958	C	Seasonal	CHUADANGA REGION KILN CLUSTER	PLANT	145
Khulna	23.564721	89.130754	C	Seasonal	JHENAIDAH REGION KILN CLUSTER	PLANT	410
Khulna	23.175359	89.152725	C	Seasonal	JESSORE REGION KILN CLUSTER	PLANT	282
Khulna	22.607007	89.07519	C	Seasonal	SATKHIRA REGION KILN CLUSTER	PLANT	392
Khulna	22.719442	89.553536	C	Seasonal	KHULNA REGION KILN CLUSTER	PLANT	172
Khulna	22.446006	89.745712	C	Seasonal	BAGERHAT REGION KILN CLUSTER	PLANT	185
Mymensingh	24.932806	89.808713	C	Seasonal	JAMALPUR REGION KILN CLUSTER	PLANT	97
Mymensingh	25.074273	90.086912	C	Seasonal	SHERPUR REGION KILN CLUSTER	PLANT	723
Mymensingh	24.747999	90.398679	C	Seasonal	MYMENSINGH REGION KILN CLUSTER	PLANT	185
Mymensingh	24.876328	90.816347	C	Seasonal	NETROKONA REGION KILN CLUSTER	PLANT	84
Rajshahi	25.11	89.069989	C	Seasonal	JOYPURHAT REGION KILN CLUSTER	PLANT	454
Rajshahi	24.937312	88.717458	C	Seasonal	NOAGAON REGION KILN CLUSTER	PLANT	190
Rajshahi	24.846661	89.370548	C	Seasonal	BOGRA REGION KILN CLUSTER	PLANT	269
Rajshahi	23.65665	90.153143	C	Seasonal	NAWABGANJ REGION KILN CLUSTER	PLANT	401
Rajshahi	24.383753	88.608708	C	Seasonal	RAJSHAHI REGION KILN CLUSTER	PLANT	278
Rajshahi	24.371804	89.02162	C	Seasonal	NATORE REGION KILN CLUSTER	PLANT	278
Rajshahi	24.432719	89.596795	C	Seasonal	SIRAJGANJ REGION KILN CLUSTER	PLANT	238

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Rajshahi	24.01	89.250307	C	Seasonal	PABNA REGION KILN CLUSTER	PLANT	75
Rangpur	26.335187	88.557065	C	Seasonal	PANCHAGARH REGION KILN CLUSTER	PLANT	203
Rangpur	26.036299	88.418663	C	Seasonal	THAKURGAON REGION KILN CLUSTER	PLANT	123
Rangpur	25.995	88.942531	C	Seasonal	NILPHAMARI REGION KILN CLUSTER	PLANT	75
Rangpur	26.07129	89.190216	C	Seasonal	LALMONIRHAT REGION KILN CLUSTER	PLANT	264
Rangpur	25.744178	89.274085	C	Seasonal	RANGPUR REGION KILN CLUSTER	PLANT	163
Rangpur	25.807563	89.64396	C	Seasonal	KURIGRAM REGION KILN CLUSTER	PLANT	247
Rangpur	25.31	89.53182	C	Seasonal	GAIBANDHA REGION KILN CLUSTER	PLANT	141
Sylhet	24.931453	91.356609	C	Seasonal	SUNAMGANJ REGION KILN CLUSTER	PLANT	432
Sylhet	24.939815	92.03391	C	Seasonal	SYLHET REGION KILN CLUSTER	PLANT	291
Sylhet	24.491225	91.871026	C	Seasonal	MOULVIBAZAR REGION KILN CLUSTER	PLANT	220
Sylhet	24.363917	91.417847	C	Seasonal	HOBIGANJ REGION KILN CLUSTER	PLANT	190
Sylhet	24.385474	90.924064	C	Seasonal	KISHOREGANJ REGION KILN CLUSTER	PLANT	314
Barisal	22.668889	90.608056	S	Seasonal		PLANT	3.65
Chittagong	22.221667	92.028889	S	Seasonal		PLANT	3.65
Chittagong	22.3575	91.9125	S	Seasonal		PLANT	3.65
Chittagong	22.428611	91.884444	S	Seasonal		PLANT	3.65
Chittagong	22.428611	91.884444	S	Seasonal		PLANT	3.65
Chittagong	22.552222	91.785278	S	Seasonal		PLANT	3.65

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Chittagong	22.913056	91.233056	S	Seasonal		PLANT	3.65
Chittagong	22.920278	91.215	S	Seasonal		PLANT	3.65
Chittagong	22.938333	91.228056	S	Seasonal		PLANT	3.65
Chittagong	22.939167	91.230556	S	Seasonal		PLANT	3.65
Chittagong	22.940556	91.260278	S	Seasonal		PLANT	3.65
Chittagong	22.941111	91.279444	S	Seasonal		PLANT	3.65
Chittagong	22.941389	91.208056	S	Seasonal		PLANT	3.65
Chittagong	22.943333	91.313889	S	Seasonal		PLANT	3.65
Chittagong	22.943611	91.282778	S	Seasonal		PLANT	3.65
Chittagong	22.948889	91.318056	S	Seasonal		PLANT	3.65
Chittagong	22.950278	91.323889	S	Seasonal		PLANT	3.65
Chittagong	22.951389	91.246389	S	Seasonal		PLANT	3.65
Chittagong	22.951944	91.201389	S	Seasonal		PLANT	3.65
Chittagong	22.959444	90.819444	S	Seasonal		PLANT	3.65
Chittagong	22.965	91.223056	S	Seasonal		PLANT	3.65
Chittagong	22.983056	91.315833	S	Seasonal		PLANT	3.65
Chittagong	23	90.801111	S	Seasonal		PLANT	3.65
Chittagong	23.003333	91.235833	S	Seasonal		PLANT	3.65
Chittagong	23.015833	91.295556	S	Seasonal		PLANT	3.65
Chittagong	23.038056	91.163611	S	Seasonal		PLANT	3.65
Chittagong	23.04	91.218333	S	Seasonal		PLANT	3.65
Chittagong	23.040556	91.165833	S	Seasonal		PLANT	3.65
Chittagong	23.041111	91.183056	S	Seasonal		PLANT	3.65
Chittagong	23.041667	91.193056	S	Seasonal		PLANT	3.65

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Chittagong	23.051667	91.145556	S	Seasonal		PLANT	3.65
Chittagong	23.0825	91.2025	S	Seasonal		PLANT	3.65
Chittagong	23.095833	91.976111	S	Seasonal		PLANT	3.65
Chittagong	23.095833	91.976111	S	Seasonal		PLANT	3.65
Chittagong	23.115	91.190278	S	Seasonal		PLANT	3.65
Chittagong	23.459722	91.004444	S	Seasonal		PLANT	3.65
Chittagong	24.794444	92.0675	S	Seasonal		PLANT	3.65
Dhaka	23.199167	90.068611	S	Seasonal		PLANT	3.65
Dhaka	23.226389	89.996111	S	Seasonal		PLANT	3.65
Dhaka	23.615556	90.43	S	Seasonal		PLANT	3.65
Dhaka	23.635	90.462778	S	Seasonal		PLANT	3.65
Dhaka	23.659722	90.140556	S	Seasonal		PLANT	3.65
Dhaka	23.830833	90.485	S	Seasonal		PLANT	3.65
Dhaka	23.870833	89.982778	S	Seasonal		PLANT	3.65
Dhaka	23.918611	90.2375	S	Seasonal		PLANT	3.65
Khulna	22.681111	89.099722	S	Seasonal		PLANT	3.65
Khulna	23.123333	89.136111	S	Seasonal		PLANT	3.65
Khulna	23.174167	89.524167	S	Seasonal		PLANT	3.65
Khulna	23.409444	89.1225	S	Seasonal		PLANT	3.65
Khulna	23.410278	89.119444	S	Seasonal		PLANT	3.65
Rajshahi	24.121425	89.143641	S	Seasonal		PLANT	3.65
Rajshahi	24.125147	89.134973	S	Seasonal		PLANT	3.65
Rangpur	25.87783	88.173826	S	Seasonal		PLANT	3.65
Sylhet	24.3975	91.744444	S	Seasonal		PLANT	3.65

City	Latitude	Longitude	Precision	Industry Type	Site Name	Site Type	Capacity (mil. bricks/year)
Sylhet	24.794444	92.0675	S	Seasonal		PLANT	3.65

Table A3. Materials database – Bangladesh – cement (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Mongla	23.06528	89.3775	A. R Cement Mills Ltd.	Cyclical, Seasonal	Noapara Plant	PLANT	0.6	CEM II	7.38	ESTIMATED
Rajshahi	25.103	89.02648	A. R Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.82397	90.42094	Ahad Corporation Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	23.00923	89.4178	Ahad Corporation Ltd.	Cyclical, Seasonal	Noapara Plant	PLANT	0.6		7.38	ESTIMATED
Dhaka	23.72882	90.41863	AKIJ Cement Company Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.62498	90.5142	AKIJ Cement Company Ltd.	Cyclical, Seasonal	Shitalaksha River Plant	PLANT	1.2	CEM II	14.76	ESTIMATED
Chittagong	22.33846	91.81355	Alhaj Mostafa-Hakim Cement Industries Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.53194	91.70083	Alhaj Mostafa-Hakim Cement Industries Ltd.	Cyclical, Seasonal	Chittagong Plant	PLANT	0.17	CEM I	2.09	ESTIMATED
Dhaka	23.87091	90.40241	Aman Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Rajshahi	24.29113	89.56648	Aman Cement Mills Ltd.	Cyclical, Seasonal	Plant	PLANT	0.21	CEM II		
Dhaka	23.72735	90.41924	Anwar Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.60238	90.62492	Anwar Cement Ltd.	Cyclical, Seasonal	Meghna River Plant and Factory	PLANT	0.24	CEM I	3.09	PUBLISHED
Dhaka	23.53974	90.67611	Anwar Cement Ltd.	Cyclical, Seasonal	Corrugated Sheet Plant	PLANT	0.108	CEM I	1.33	ESTIMATED
Dhaka	23.72623	90.43556	Apon Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.38275	91.86962	Aramit Cement	Cyclical, Seasonal	Karnaphuli River Office and Plant	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Chittagong	22.38275	91.86962	Aramit Cement	Cyclical, Seasonal	Karnaphuli River Office and Plant	PLANT	1.33	CEM II 42.5N	16.36	ESTIMATED
Dhaka	23.77434	90.41188	Aramit Cement	Cyclical, Seasonal	Dhaka Office	OFFICE				
Dhaka	23.76576	90.40546	Aramit Cement	Cyclical, Seasonal	Dhaka Depot	TERMINAL				
Barisal	22.86922	90.31981	Aramit Cement	Cyclical, Seasonal	Barisal Depot	TERMINAL				
Khulna	22.81739	89.55368	Aramit Cement	Cyclical, Seasonal	Khulna Depot	TERMINAL				
Rajshahi	24.84389	89.36898	Aramit Cement	Cyclical, Seasonal	Bogra Depot	TERMINAL				
Sylhet	24.49417	91.77417	Aramit Cement	Cyclical, Seasonal	Sylhet Depot	TERMINAL				
Sylhet	24.73441	90.40858	Aramit Cement	Cyclical, Seasonal	Mymensingh Depot	TERMINAL				
Khulna	22.51528	89.58667	Bashundara Industrial Complex Ltd.	Cyclical, Seasonal	Pashure River Plant	PLANT	1.2	CEM II 42.5N	14.76	ESTIMATED
Rajshahi	23.60626	90.51099	Bashundara Industrial Complex Ltd.	Cyclical, Seasonal	Madanganj Plant	PLANT	0.4	CEM II 42.5N	4.92	ESTIMATED
Dhaka	23.58694	90.51528	Bashundara Industrial Complex Ltd.	Cyclical, Seasonal	Shitalakshya River Plant	PLANT	2.1	CEM II 42.5N	25.83	ESTIMATED
Dhaka	23.81188	90.4301	Bashundara Industrial Complex Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.73923	90.38712	Bengal Agencies	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.94611	90.61556	Bengal Agencies/Siam Bangla Industries Ltd.	Cyclical, Seasonal	Cement Plant	PLANT		CEM I		
Dhaka	23.74634	90.39291	Bengal Agencies/Siam Bangla Industries Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.78481	90.34701	Brother Corporation	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.72737	90.41593	Brother Corporation	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.75349	90.39226	CEMEX Cement Bangladesh Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.59949	90.5105	CEMEX Cement Bangladesh Ltd.	Cyclical, Seasonal	Shitalakshya River Plant - Grinding Mill	PLANT	0.55	CEM II 42.5N	6.77	ESTIMATED
Sylhet	25.04778	91.65778	Chhatak Cement Company Ltd.	Cyclical, Seasonal	Chhatak Plant	PLANT	0.233	CEM I	2.87	ESTIMATED
Chittagong	22.32336	91.81187	Confidence Cement Ltd.	Cyclical, Seasonal	Chittagong Office	OFFICE				
Chittagong	22.44155	91.73802	Confidence Cement Ltd.	Cyclical, Seasonal	Plant	PLANT	0.75	CEM II 42.5N	108.00	PUBLISHED
Dhaka	23.75067	90.39192	Confidence Cement Ltd.	Cyclical, Seasonal	Head Office	OFFICE				
Dhaka	23.72506	90.42128	Confidence Cement Ltd.	Cyclical, Seasonal	Share Office	OFFICE				
Dhaka	23.79553	90.40801	Deshbandhu Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Rajshahi	24.12783	89.587	Deshbandhu Cement Mills Ltd.	Cyclical, Seasonal	Cement Factory	PLANT	0.7		8.61	ESTIMATED
Chittagong	22.32466	91.82495	Diamond Cement Ltd.	Cyclical, Seasonal	Head Office	OFFICE				
Chittagong	22.30778	91.81361	Diamond Cement Ltd.	Cyclical, Seasonal	Karnaphuli River Plant	PLANT	1.33	CEM II 42.5N	16.36	ESTIMATED
Dhaka	23.77191	90.41154	Diamond Cement Ltd.	Cyclical, Seasonal	Chittagong Office	OFFICE				
Dhaka	23.73844	90.3811	Dubai Bangladesh Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	22.81479	89.56386	Dubai Bangladesh Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	22.50347	89.59095	Dubai Bangladesh Cement Mills Ltd.	Cyclical, Seasonal	Mongla Cement Plant	PLANT	0.6	CEM II 42.5N	7.38	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Re-quirements (MW)	Electric Requirement Source
Dhaka	23.74389	90.39501	Eastern Cement Industries Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.66802	90.52455	Eastern Cement Industries Ltd.	Cyclical, Seasonal	Shitalakshya River Plant	PLANT	0.6	CEM II 42.5N	7.38	ESTIMATED
Dhaka	23.74395	90.39201	Emech Corporation	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.82324	90.41976	G. M. Steel Agency	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.74627	90.37545	Gemcon Group Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	22.91885	89.5144	Gemcon Group Ltd.	Cyclical, Seasonal	Khulna Cement Plant	PLANT	0.5		6.15	ESTIMATED
Chittagong	22.27987	91.79556	Heidelberg Cement Bangladesh Ltd.	Cyclical, Seasonal	Karnaphuli River Office and Plant	OFFICE				
Chittagong	22.27987	91.79556	Heidelberg Cement Bangladesh Ltd.	Cyclical, Seasonal	Karnaphuli River Office and Plant	PLANT	1.45	CEM II	10.9	PUBLISHED
Dhaka	23.77563	90.41655	Heidelberg Cement Bangladesh Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.71296	90.51541	Heidelberg Cement Bangladesh Ltd.	Cyclical, Seasonal	Shitalakshya River Plant	PLANT	1.2	CEM II	14.76	ESTIMATED
Dhaka	23.73299	90.40132	Imam Group	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.79384	90.40443	Imam Group	Cyclical, Seasonal	Head Office	OFFICE				
Dhaka	23.89528	90.58861	Imam Group/ Bengal Tiger Cement Industry Ltd.	Cyclical, Seasonal	Cement Plant	PLANT	0.1095	CEM II	1.35	ESTIMATED
Dhaka	25.04778	91.65778	Imam Group/ Prime Cement Ltd.	Cyclical, Seasonal	Cement Plant	PLANT	0.0365	CEM II	0.45	ESTIMATED
Dhaka	23.72722	90.42002	Karim Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	23.04167	89.39111	Karim Cement Mills Ltd.	Cyclical, Seasonal	Cement Mills	PLANT	0.073		0.90	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.76077	90.42077	Khan Enterprise	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.78381	90.41655	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.70005	90.51725	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Katchpur Depot	TERMINAL				
Dhaka	23.6457	90.59914	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Kutubpur Terminal	TERMINAL				
Dhaka	23.78412	90.33026	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Mirpur Depot	TERMINAL				
Dhaka	23.78417	90.34295	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Dipnagor Depot	TERMINAL				
Khulna	########	########	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Nowapara Depot	TERMINAL				
Sylhet	25.03666	91.64739	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Surma River Plant	PLANT	1.5	CEM II 42.5N	18.45	ESTIMATED
Sylhet	24.91213	91.8498	Lafarge Surma Cement Ltd.	Cyclical, Seasonal	Sylhet Depot (Sales Office)	TERMINAL				
Dhaka	23.77136	90.40363	LafargeHolcim Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.61148	90.61234	LafargeHolcim Ltd.	Cyclical, Seasonal	Meghna River Plant: Holcim (Bangladesh) Ltd	PLANT	1	CEM II 42.5N	12.30	ESTIMATED
Dhaka	23.60889	90.60889	LafargeHolcim Ltd.	Cyclical, Seasonal	Meghna River Plant: United Cement Industries Ltd	PLANT	0.7	CEM II 42.5N	8.61	ESTIMATED
Dhaka	22.50517	89.58986	LafargeHolcim Ltd.	Cyclical, Seasonal	Pashure River Plant : Saiham Cement Industries Ltd	PLANT	0.5	CEM II 42.5N	6.15	ESTIMATED
Dhaka	23.72697	90.42132	Levatus (Bangladesh) Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.33134	91.84641	M.I. Cement Factory Ltd.	Cyclical, Seasonal	Liason Office	OFFICE				
Dhaka	23.79312	90.41536	M.I. Cement Factory Ltd.	Cyclical, Seasonal	Head Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.57589	90.50824	M.I. Cement Factory Ltd.	Cyclical, Seasonal	Dhaleshwari River Plant	PLANT	1.74	CEM II 42.5N	21.40	ESTIMATED
Khulna	23.06694	89.37694	Macca Cement Mills Ltd.	Cyclical, Seasonal	Cement Mills	PLANT				
Dhaka	23.74215	90.38484	Madina Cement Industries Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.60799	90.60855	Madina Cement Industries Ltd.	Cyclical, Seasonal	Meghna River Plant	PLANT	1.69	CEM II 42.5N	20.79	ESTIMATED
Dhaka	23.71998	90.35735	Madina Cement Industries Ltd.	Cyclical, Seasonal	Buriganga River Plant	PLANT	0.09	CEM II 42.5N	1.11	ESTIMATED
Khulna	22.51528	89.58667	Meghna Cement Mills Ltd.	Cyclical, Seasonal	Pashure River Plant	PLANT	1	CEM II 42.5N	12.30	ESTIMATED
Dhaka	23.8245	90.42966	Meghna Cement Mills Ltd. /Bashundara Industrial Complex Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.72695	90.41674	Metrocem Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.57406	90.51236	Metrocem Cement Ltd.	Cyclical, Seasonal	Dhaleshwari River Plant	PLANT	0.13	CEM II	1.60	ESTIMATED
Dhaka	23.75411	90.37478	Mir Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.77077	90.5129	Mir Cement Ltd.	Cyclical, Seasonal	Shitalaksha River Plant	PLANT	0.18	CEM II 42.5N	2.21	ESTIMATED
Dhaka	23.72689	90.42278	Modern Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.77839	90.3954	Mongla Cement Factory	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	22.46966	89.60659	Mongla Cement Factory	Cyclical, Seasonal	Project Office	OFFICE				
Khulna	22.51641	89.5867	Mongla Cement Factory	Cyclical, Seasonal	Pashure River Plant	PLANT	0.6	CEM II 42.5N	7.38	ESTIMATED
Dhaka	23.75023	90.39062	Musky Enterprises Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.7803	90.40607	Nitol Cement Industries Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	23.12083	89.34389	Nitol Cement Industries Ltd.	Cyclical, Seasonal	Grey Cement Mills	PLANT	0.13		1.60	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Khulna	23.10806	89.35472	Nitol Cement Industries Ltd.	Cyclical, Seasonal	White Cement Mills	PLANT	0.02		0.25	ESTIMATED
Dhaka	23.75583	90.37494	Noapara Cement Mills Ltd.	Cyclical, Seasonal	Dhaka Office	OFFICE				
Dhaka	23.74377	90.38349	Noapara Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	23.02002	89.40899	Noapara Cement Mills Ltd.	Cyclical, Seasonal	Noapara Plant	PLANT	0.1	CEM II	1.23	ESTIMATED
Khulna	23.06333	89.37861	Noapara Cement Mills Ltd.	Cyclical, Seasonal	Cement Mills	PLANT				
Dhaka	23.75242	90.39536	Olympic Cement Ltd.	Cyclical, Seasonal	Khansons Group Office	OFFICE				
Dhaka	23.79399	90.40532	Olympic Cement Ltd.	Cyclical, Seasonal	Olympic Cement Office	OFFICE				
Barisal	22.65186	90.34523	Olympic Cement Ltd.	Cyclical, Seasonal	Kirtonkhola River Plant	PLANT	1.2		14.76	ESTIMATED
Dhaka	23.77462	90.41321	Pacific Cement Industries (BD) Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.32703	91.8107	Premier Cement Mills Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
Dhaka	23.75122	90.3933	Premier Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.57944	90.51278	Premier Cement Mills Ltd.	Cyclical, Seasonal	Shitalakshya River Plant	PLANT	2.4	CEM II 42.5N	5.34	PUBLISHED
Dhaka	23.85134	90.41351	Rabbani Trading Corporation	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.32804	91.81223	Royal Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.50231	91.71496	Royal Cement Ltd.	Cyclical, Seasonal	Plant	PLANT	1.15		10.80	PUBLISHED
Dhaka	23.7269	90.42136	Russel Group of Companies	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.31194	91.8579	S. Alam Cement Ltd.	Cyclical, Seasonal	Kharnaphuli River Plant	PLANT	0.43	CEM II 42.5N	6.00	PUBLISHED
Chittagong	22.33765	91.84398	S. Alam Cement Ltd. /Portman Cements Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Chittagong	22.31194	91.8579	S. Alam Cements Ltd./ Portman Cements Ltd.	Cyclical, Seasonal	Kharnaphuli River Plant	PLANT	0.18	CEM II 42.5N	6.00	PUBLISHED
Dhaka	23.71373	90.40587	S. Co. Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.78847	90.41614	S.B. Group	Cyclical, Seasonal	Corporate Office	OFFICE				
Khulna	22.90808	89.51613	S.B. Group	Cyclical, Seasonal	Cement Mills	PLANT	0.52	CEM II 42.5N	6.40	ESTIMATED
Dhaka	23.93361	90.61167	Seven Circle (BD) Ltd.	Cyclical, Seasonal	Shitalakshya River Plant	PLANT	1.6	CEM II 42.5N	15.26	PUBLISHED
Dhaka	23.7948	90.41492	Seven Circle (BD) Ltd. /Shun Shing Cement Mills Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.78646	90.34671	Shah Ali Cement Traders	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.79567	90.41571	Shah Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.57022	90.5221	Shah Cement	Cyclical, Seasonal	Dhaleshwari River Plant	PLANT	5.2	CEM II 42.5N	17.00	PUBLISHED
Khulna	22.78481	89.5812	Shun Shing Cement Mills Ltd.	Cyclical, Seasonal	Rupsa River Plant	PLANT	1.3	CEM II 42.5N	15.26	PUBLISHED
Dhaka	23.78343	90.34005	Shuvro Group	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.79401	90.40397	Ultratech Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
Dhaka	23.57327	90.5127	Ultratech Cement	Cyclical, Seasonal	Dhaka Plant	PLANT	0.5	CEM II 32.5N	6.15	ESTIMATED
Dhaka	23.79311	90.41545	Ultratech Cement/Emirates Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Chittagong	22.32706	91.81283	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Uttara Office	OFFICE				
Chittagong	22.37457	91.77724	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Chittagong Depot	PLANT	0.144	CEM II	1.77	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Re-quirements (MW)	Electric Requirement Source
Dhaka	23.78732	90.41461	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Head Office	OFFICE				
Dhaka	23.87067	90.39091	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Chittagong Office	OFFICE				
Dhaka	23.61296	90.60986	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Meghna River Plant	PLANT	3.6	CEM II	35.65	PUBLISHED
Dhaka	23.91185	90.38895	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Tongi Depot	TERMINAL				
Dhaka	23.76037	90.39158	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Tejgaon Depot	TERMINAL				
Barisal	22.70069	90.3534	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Barisal Depot	TERMINAL				
Rangpur	25.74457	89.27112	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Rangpur Depot	TERMINAL				
Rajshahi	24.86666	89.35872	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Bogra Depot	TERMINAL				
Sylhet	24.48961	91.75584	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Mowlovibazar Depot	TERMINAL				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Sylhet	24.89096	91.86642	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Sylhet Depot	PLANT	0.144	CEM II	1.77	ESTIMATED
Mymensingh	24.73441	90.40858	Unique Cement Industries Ltd. /Fresh Cement Industries Ltd.	Cyclical, Seasonal	Mymensingh Depot	TERMINAL				

Table A4. Materials database – India – cement (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Chhattisgarh	21.23841	81.38284	ACC	Cyclical, Seasonal	Jamul Plant	PLANT	2.80	CEM I 43	34.44	ESTIMATED
Jharkland	22.42364	85.75439	ACC	Cyclical, Seasonal	Chaibasa Plant	PLANT	1.20	CEM I 43	15	PUBLISHED
Jharkland	23.78715	86.4274	ACC	Cyclical, Seasonal	Sindri Plant	PLANT	0.60	CEM I 43	7.38	ESTIMATED
Odissa	21.3728	83.61671	ACC	Cyclical, Seasonal	Bargarh Plant	PLANT	0.96	CEM I 43	11.81	ESTIMATED
West Bengal	23.63625	86.88793	ACC	Cyclical, Seasonal	Damodhar Plant	PLANT	0.60	CEM I 43	7.38	ESTIMATED
West Bengal	22.51737	88.40167	ACC	Cyclical, Seasonal	Eastern Region Office (Kolkata)	OFFICE				
Meghalaya	25.19351	92.36168	Adhunik Cement Ltd.	Cyclical, Seasonal	Adhunik Cement Ltd. Plant	PLANT	1.5	CEM I 43	25	PUBLISHED
West Bengal	22.577	88.3491	Adhunik Cement Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
West Bengal	22.53991	88.3551	Adhunik Cement Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
Assam	26.17812	91.74473	Aditi Industries	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.53187	92.9318	Aditi Industries	Cyclical, Seasonal	Plant	PLANT	0.165	CEM II	2.03	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Chhattisgarh	21.67307	82.08553	Ambuja Cement	Cyclical, Seasonal	Bhatapara Integrated Plant	PLANT	3.50	CEM II	63	PUBLISHED
West Bengal	22.52892	88.36863	Ambuja Cement	Cyclical, Seasonal	Eastern Region Office (Kolkata)	OFFICE				
West Bengal	22.56939	88.19445	Ambuja Cement	Cyclical, Seasonal	Sankrail Grinding Unit	PLANT	2.40	CEM II	29.52	ESTIMATED
West Bengal	24.77591	87.88641	Ambuja Cement	Cyclical, Seasonal	Farakka Grinding Unit	PLANT	1.50	CEM II	18.45	ESTIMATED
Assam	26.17224	91.7965	Amrit Cement	Cyclical, Seasonal	Corporate Office - Guwahati	OFFICE				
Meghalaya	25.56849	91.88518	Amrit Cement	Cyclical, Seasonal	Registered Office - Shillong	OFFICE				
Meghalaya	25.35457	92.32094	Amrit Cement	Cyclical, Seasonal	Manufacturing Site - Meghalaya	PLANT	1		12.30	ESTIMATED
West Bengal	22.54714	88.36185	Amrit Cement	Cyclical, Seasonal	Corporate Office - Kolkata	OFFICE				
West Bengal	23.67628	87.09639	Bakreswar Cement	Cyclical, Seasonal	Plant	PLANT				
Assam	24.86601	92.58288	Barak Valley Cements Ltd.	Cyclical, Seasonal	Assam Plant	PLANT	0.27		3.37	ESTIMATED
Assam	26.17325	91.75698	Barak Valley Cements Ltd.	Cyclical, Seasonal	Assam Office	OFFICE				
Assam	24.82318	92.79679	Barak Valley Cements Ltd.	Cyclical, Seasonal	Assam Office	OFFICE				
West Bengal	22.5921	88.41869	Barak Valley Cements Ltd.	Cyclical, Seasonal	Kolkata Office	OFFICE				
West Bengal	23.67306	87.09778	Bhabani Cement	Cyclical, Seasonal	Plant	PLANT				
West Bengal	23.5625	87.23508	Birla Cement	Cyclical, Seasonal	Durgapur /Durga Hitech Cement Works	PLANT	2.3	CEM II	28.29	ESTIMATED
West Bengal	22.57034	88.34997	Birla Cement	Cyclical, Seasonal	Registered Office	OFFICE				
West Bengal	22.56364	88.35168	Birla Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	25.89694	92.99944	Bulland Cement	Cyclical, Seasonal	Plant	PLANT	0.073	CEM I 43	0.90	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Assam	26.16019	91.77175	Bulland Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
Jharkland	23.63465	85.30654	Burnapur Cement Ltd.	Cyclical, Seasonal	Patratu Plant	PLANT	0.292	CEM I 43	3.59	ESTIMATED
West Bengal	23.71875	86.95495	Burnapur Cement Ltd.	Cyclical, Seasonal	Asanol Plant	PLANT	0.365	CEM I 43	4.49	ESTIMATED
West Bengal	22.56925	88.35273	Burnapur Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.02135	93.76574	Cement Corporation of India	Cyclical, Seasonal	Bokajan Cement works	PLANT	0.3	CEM I 43	3.69	ESTIMATED
Chhattisgarh	22.00248	82.40883	Cement Corporation of India	Cyclical, Seasonal	Akaltara Cement Works	PLANT	0.4	CEM I 43	4.92	ESTIMATED
Chhattisgarh	21.33519	81.70727	Cement Corporation of India	Cyclical, Seasonal	Mandhar Cement Works	PLANT	0.4	CEM I 43	4.92	ESTIMATED
Meghalaya	25.17764	92.38928	Cement Manufacturing Co. Ltd.	Cyclical, Seasonal	Jainta Hills Plant	PLANT	0.6	CEM I 43	7.38	ESTIMATED
West Bengal	22.53671	88.33177	Cement Manufacturing Co. Ltd.	Cyclical, Seasonal	Office	OFFICE				
Chhattisgarh	21.498	81.78287	Century Cement Ltd.	Cyclical, Seasonal	Cement Works	PLANT	2.1	CEM II	26.70	PUBLISHED
West Bengal	24.38762	88.09586	Century Cement Ltd.	Cyclical, Seasonal	Sonar Bangla (Grinding Unit)	PLANT	1.5	CEM II	18.45	ESTIMATED
Assam	25.51203	92.7645	Dalmia Cement Ltd.	Cyclical, Seasonal	Assam Cement Plant	PLANT	1.72	CEM I 43	21.16	ESTIMATED
Jharkland	23.35674	85.3244	Dalmia Cement Ltd.	Cyclical, Seasonal	East Regional Office (Jharkland)	OFFICE				
Jharkland	23.6788	86.07378	Dalmia Cement Ltd.	Cyclical, Seasonal	Bokaro Cement Plant	PLANT	2.1	CEM I 43	25.83	ESTIMATED
Meghalaya	25.22674	92.38122	Dalmia Cement Ltd.	Cyclical, Seasonal	Meghalaya Cement Plant	PLANT	1.64	CEM I 43	20.20	ESTIMATED
West Bengal	22.54137	88.36658	Dalmia Cement Ltd.	Cyclical, Seasonal	East Regional Office (Kolkata)	OFFICE				
West Bengal	23.67389	87.09778	Damodar Cement Industries Ltd.	Cyclical, Seasonal	Plant	PLANT				
Assam	26.12154	91.89618	Delta Cement	Cyclical, Seasonal	Plant	PLANT				
Chhattisgarh	21.6281	82.11739	Emami Cement	Cyclical, Seasonal	Plant	PLANT	2.5	CEM I 43	40	PUBLISHED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
West Bengal	22.51677	88.40206	Emami Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
Meghalaya	25.20993	92.35124	Goldstone Cements Ltd.	Cyclical, Seasonal	Jainta Hills Plant	PLANT	2.54		40	PUBLISHED
West Bengal	22.55383	88.35668	Goldstone Cements Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.16722	91.76642	Green Valliey Industries Ltd.	Cyclical, Seasonal	Guwahati Office	OFFICE				
Meghalaya	25.24035	92.38979	Green Valliey Industries Ltd.	Cyclical, Seasonal	Jainta Hills Plant	PLANT	1		12.30	ESTIMATED
West Bengal	22.54185	88.34928	Green Valliey Industries Ltd.	Cyclical, Seasonal	Group Corpo-rate Office	OFFICE				
Bihar	26.12115	85.36625	Heidelberg Cement	Cyclical, Seasonal	Muzaffarpur Of-fice	OFFICE				
Bihar	25.61363	85.11463	Heidelberg Cement	Cyclical, Seasonal	Patna Office	OFFICE				
Chhattisgarh	22.07879	82.14528	Heidelberg Cement	Cyclical, Seasonal	Bilaspur Office	OFFICE				
West Bengal	23.5301	87.34005	Jagdamba Industries Ltd.	Cyclical, Seasonal	Plant	PLANT	0.1	CEM I 43	1.23	ESTIMATED
West Bengal	22.58213	88.4182	Jagdamba Industries Ltd.	Cyclical, Seasonal	Communication Office	OFFICE				
West Bengal	22.63437	88.41368	Jagdamba Industries Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
Chhattisgarh	21.18448	81.36652	Jaypee Cement	Cyclical, Seasonal	Bhilai Grinding Plant	PLANT	2.2	CEM II	27.06	ESTIMATED
Jharkland	23.69929	86.06415	Jaypee Cement	Cyclical, Seasonal	Bokaro Cement Plant	PLANT	2.1	CEM II	25.83	ESTIMATED
Chhattisgarh	21.35707	81.40699	JK Lakshmi Cement	Cyclical, Seasonal	Durg Cement Plant	PLANT	2.7	CEM I 43	33.21	ESTIMATED
Arunachal Pradesh	28.22877	94.72224	Jud Cements Ltd.	Cyclical, Seasonal	Arunachal Pradesh Depot	TERMINAL				
Assam	26.16094	91.77362	Jud Cements Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.49218	90.55071	Jud Cements Ltd.	Cyclical, Seasonal	Lower Assam Depot	TERMINAL				
Assam	26.14278	91.72894	Jud Cements Ltd.	Cyclical, Seasonal	Guwahati Depot	TERMINAL				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Assam	26.33999	92.67518	Jud Cements Ltd.	Cyclical, Seasonal	Nagaon Depot	TERMINAL				
Assam	24.86368	92.5623	Jud Cements Ltd.	Cyclical, Seasonal	Badarpor Depot	TERMINAL				
Assam	26.65023	92.78736	Jud Cements Ltd.	Cyclical, Seasonal	Tezpur Depot	TERMINAL				
Assam	24.83408	92.77574	Jud Cements Ltd.	Cyclical, Seasonal	Silchar Depot	TERMINAL				
Assam	26.52415	93.96244	Jud Cements Ltd.	Cyclical, Seasonal	Golaghat Depot	TERMINAL				
Assam	26.74833	94.20453	Jud Cements Ltd.	Cyclical, Seasonal	Jorhat Depot	TERMINAL				
Assam	27.22382	94.09388	Jud Cements Ltd.	Cyclical, Seasonal	Lakhimpur Depot	TERMINAL				
Assam	26.9827	94.64213	Jud Cements Ltd.	Cyclical, Seasonal	Sibsagar Depot	TERMINAL				
Assam	27.47245	94.90867	Jud Cements Ltd.	Cyclical, Seasonal	Dibrugarh Depot	TERMINAL				
Assam	27.49177	95.34538	Jud Cements Ltd.	Cyclical, Seasonal	Tinsukia Depot	TERMINAL				
Manipur	24.67112	93.75792	Jud Cements Ltd.	Cyclical, Seasonal	Manipur Depot	TERMINAL				
Meghalaya	25.19043	92.403	Jud Cements Ltd.	Cyclical, Seasonal	Factory Site	PLANT	0.5	CEM I 43	6.15	ESTIMATED
Meghalaya	25.58016	91.89586	Jud Cements Ltd.	Cyclical, Seasonal	Shillong Depot	TERMINAL				
Mizoram	23.44734	92.74032	Jud Cements Ltd.	Cyclical, Seasonal	Mizoram Depot	TERMINAL				
Nagaland	26.03784	94.5635	Jud Cements Ltd.	Cyclical, Seasonal	Nagaland Depot	TERMINAL				
Tripura	23.83144	91.28334	Jud Cements Ltd.	Cyclical, Seasonal	Agartala Depot	TERMINAL				
Tripura	24.37939	92.14933	Jud Cements Ltd.	Cyclical, Seasonal	Dharmanagar Depot	TERMINAL				
Bihar	24.67044	83.98921	Kalyanpur Cements Ltd.	Cyclical, Seasonal	Banjari Cement Works	PLANT	1		12.30	ESTIMATED
Bihar	25.61493	85.14224	Kalyanpur Cements Ltd.	Cyclical, Seasonal	Head Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
West Bengal	23.6775	87.14	Kamdhenu Cement	Cyclical, Seasonal	Plant	PLANT	1.5			
West Bengal	23.6125	87.15028	Khaitan Cement	Cyclical, Seasonal	Plant	PLANT				
Chhattisgarh	21.73218	82.21352	Lafarge	Cyclical, Seasonal	Sonadih Cement Plant	PLANT	2.75	CEM II	33.83	ESTIMATED
Chhattisgarh	21.96638	82.35214	Lafarge	Cyclical, Seasonal	Arasmeta Cement Plant	PLANT	2.75	CEM II	33.83	ESTIMATED
Jharkland	22.7539	86.24462	Lafarge	Cyclical, Seasonal	Jojobera Cement Plant	PLANT	2.75	CEM II	33.83	ESTIMATED
West Bengal	22.59854	88.40292	Lafarge	Cyclical, Seasonal	East Regional Office (Kolkata)	OFFICE				
West Bengal	23.46041	87.1348	Lafarge	Cyclical, Seasonal	Mejia Cement Plant	PLANT	2.75	CEM II	33.83	ESTIMATED
West Bengal	23.6175	87.14722	Mangalpur Cement	Cyclical, Seasonal	Plant	PLANT				
Meghalaya	25.25991	91.71239	Mawmluh-Cherra Cements Ltd.	Cyclical, Seasonal	Plant	PLANT	0.2		2.46	ESTIMATED
Meghalaya	25.57862	91.89316	Mawmluh-Cherra Cements Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
West Bengal	23.61222	87.14389	MB Group	Cyclical, Seasonal	Shristi Cement Plant	PLANT				
Assam	26.1553	91.7794	Meghalaya Cements Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
Meghalaya	25.20392	92.37838	Meghalaya Cements Ltd.	Cyclical, Seasonal	Plant	PLANT	1.314	CEM I 43	10	PUBLISHED
West Bengal	22.59733	88.41265	Meghalaya Cements Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Bihar	25.5808	84.86562	Nirman Cements Ltd.	Cyclical, Seasonal	Factory Site	PLANT				
Bihar	25.61001	85.14165	Nirman Cements Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	25.58722	92.01028	None	Cyclical, Seasonal	Mawpdang Cement Plant	PLANT				
Meghalaya	25.60472	91.18056	None	Cyclical, Seasonal	Cement Factory	PLANT				
Odissa	22.19762	84.58726	OCL India Ltd.	Cyclical, Seasonal	Rajgangpur Cement Plant	PLANT	4	CEM I 43	49.20	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Odissa	20.62531	85.995	OCL India Ltd.	Cyclical, Seasonal	Kapilash Cement Works	PLANT	1.35	CEM I 43	16.61	ESTIMATED
West Bengal	22.57265	88.36395	OCL India Ltd.	Cyclical, Seasonal	Head Office	OFFICE				
West Bengal	23.71306	86.94417	Omni Cement Pvt. Ltd.	Cyclical, Seasonal	Mini Cement Plant	PLANT				
Odissa	20.29569	85.83503	Orient Cement	Cyclical, Seasonal	Bhubaneshwar Office	OFFICE				
Assam	26.11281	91.79808	Purbanchal Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.06057	91.88338	Purbanchal Cement Ltd.	Cyclical, Seasonal	Plant	PLANT	0.4	CEM I 43	4.94	ESTIMATED
West Bengal	22.54425	88.36039	Purbanchal Cement Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
Assam	26.11319	91.89145	Raksha Cements Pvt Ltd.	Cyclical, Seasonal	Factory Site	PLANT	0.06	CEM I 43	0.74	ESTIMATED
Assam	26.16018	91.77173	Raksha Cements Pvt Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
West Bengal	22.42199	87.86247	Ramco Cement	Cyclical, Seasonal	Kolaghat Grinding Unit	PLANT	0.95	CEM I 43		
West Bengal	22.36836	87.02525	Rashmi Group	Cyclical, Seasonal	Cement Works	PLANT	0.2	CEM I 43	2.46	ESTIMATED
West Bengal	22.54466	88.35882	Rashmi Group	Cyclical, Seasonal	Registered Office	OFFICE				
West Bengal	22.54144	88.36643	Rashmi Group	Cyclical, Seasonal	Corporate Office	OFFICE				
Jharkland	23.69235	85.51652	Rishi Cement Company Ltd.	Cyclical, Seasonal	Cement Works	PLANT	0.3	CEM I 43	3.69	ESTIMATED
West Bengal	22.51416	88.32793	Rishi Cement Company Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.16835	91.76404	RNB Cements (P) Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Meghalaya	25.57625	91.88137	RNB Cements (P) Ltd.	Cyclical, Seasonal	Registered Office	OFFICE				
Meghalaya	25.66446	91.91109	RNB Cements (P) Ltd.	Cyclical, Seasonal	Plant	PLANT	0.438	CEM I 43	10	PUBLISHED
Meghalaya	25.57775	91.8815	RNB Cements (P) Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
West Bengal	23.67361	87.09944	Satwick Cement	Cyclical, Seasonal	Plant	PLANT				
Odissa	22.24224	84.80019	Shiva Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Odissa	22.23448	84.7418	Shiva Cement Ltd.	Cyclical, Seasonal	Kalunga Cement Works	PLANT	1.3	CEM I 43	15.99	ESTIMATED
Odissa	22.21194	84.43041	Shiva Cement Ltd.	Cyclical, Seasonal	Telighana Cement Works	PLANT	1.3	CEM I 43	15.99	ESTIMATED
Bihar	24.77518	84.35119	Shree Cement	Cyclical, Seasonal	Bihar Grinding Unit	PLANT	2	CEM I 43	12	PUBLISHED
Chhattisgarh	21.60725	82.08349	Shree Cement	Cyclical, Seasonal	Chhattisgarh Cement Plant	PLANT	2.6	CEM I 43	113	PUBLISHED
West Bengal	22.57529	88.34689	Shree Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
West Bengal	23.61556	87.1475	Shyam Group	Cyclical, Seasonal	Plant	PLANT				
West Bengal	22.56704	88.35387	Shyam Group	Cyclical, Seasonal	Registered Office	OFFICE				
West Bengal	22.56811	88.35599	Shyam Group	Cyclical, Seasonal	Main Office	OFFICE				
West Bengal	23.67583	87.14778	Srijan Cement	Cyclical, Seasonal	Plant	PLANT	0.6	CEM I	7.38	ESTIMATED
Assam	26.1738	91.73222	Taj Cement Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Meghalaya	25.22583	92.38417	Taj Cement Ltd.	Cyclical, Seasonal	Registered Of-fice and Works	PLANT	1	CEM I 43	10	PUBLISHED
Assam	25.98365	90.77953	Ultrabond Cement	Cyclical, Seasonal	Corporate Office	OFFICE				
Assam	26.18171	91.73852	Ultrabond Cement	Cyclical, Seasonal	Corporate Of-fice	OFFICE				
Chhattisgarh	21.57755	82.02042	Ultratech Cement	Cyclical, Seasonal	Rawan Cement Works (Compo-site Plant)	PLANT	3.3	CEM I 43	45.3	PUBLISHED
Chhattisgarh	21.54372	81.94731	Ultratech Cement	Cyclical, Seasonal	Hirmi Cement Works (Compo-site Plant)	PLANT	1.9	CEM I 43	23.37	ESTIMATED
Odissa	21.8914	84.09831	Ultratech Cement	Cyclical, Seasonal	Jharsuguda Cement Works (Grinding Unit)	PLANT	0.767	CEM I 43	9.43	ESTIMATED

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
West Bengal	23.49281	87.36227	Ultratech Cement	Cyclical, Seasonal	West Bengal Cement Works (Grinding Unit)	PLANT	2.19	CEM I 43	26.94	ESTIMATED

Table A5. Materials database – Myanmar – cement (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Mandalay	21.57836	96.23386	Arr Thit Man	Cyclical, Seasonal	Kyaukse Cement Plant	PLANT	1.825		22.45	ESTIMATED
Shan	20.10867	96.7839	Dragon Cement	Cyclical, Seasonal	Pinlaung Cement Plant	PLANT	0.24		2.95	ESTIMATED
Yangon	16.83046	96.12183	Dragon Cement	Cyclical, Seasonal	Head Office	OFFICE				
Mandalay	21.58703	96.20809	Jiangsu Pengfei Group Co. Ltd./ Tigerhead Cement	Cyclical, Seasonal	Kyaukse Cement Plant	PLANT	0.9		11.07	ESTIMATED
Mandalay	21.58703	96.20809	Jiangsu Pengfei Group Co. Ltd./AAA Cement International Co. Ltd.	Cyclical, Seasonal	Kyaukse Cement Plant	PLANT	0.36		4.43	ESTIMATED
Mandalay	21.97637	96.08242	Jiangsu Pengfei Group Co. Ltd./AAA Cement International Co. Ltd.	Cyclical, Seasonal	Head Office	OFFICE				
Yangon	16.82437	96.12886	Jiangsu Pengfei Group Co. Ltd./AAA Cement International Co. Ltd.	Cyclical, Seasonal	Yangon Office	OFFICE				
Mandalay	21.9305	96.11049	Mandalay Cement Industries Ltd.	Cyclical, Seasonal	Head Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Quality	Electric Requirements (MW)	Electric Requirement Source
Mandalay	21.58703	96.20809	Mandalay Cement Industries Ltd.	Cyclical, Seasonal	Kyaukse Cement Plant	PLANT	0.15			
Mandalay	21.58703	96.20809	Mawkeinnay Cement	Cyclical, Seasonal	Cement Plant	PLANT	0.002		0.02	ESTIMATED
Bago	19.51525	96.39917	Max Cement	Cyclical, Seasonal	Taung Phi Lar Plant	PLANT	0.18	CEM I 42.5	4.15	PUBLISHED
Mandalay	20.77503	96.40063	Max Cement	Cyclical, Seasonal	Pyi Nyaung Plant	PLANT	0.18	CEM I 42.5	5.00	PUBLISHED
Yangon	16.78566	96.15593	Max Cement	Cyclical, Seasonal	Head Office	OFFICE				
Kayin	16.88544	97.61249	Myanmar Economic Corporation	Cyclical, Seasonal	Hpa An Cement Plant	PLANT	0.24		2.95	ESTIMATED
Kayin	16.88544	97.61249	Myanmar Economic Corporation	Cyclical, Seasonal	Hpa An Cement Plant	PLANT	1.20		14.76	ESTIMATED
Mandalay	16.87636	97.64473	Myanmar Economic Corporation	Cyclical, Seasonal	Hsinmin Cement Ltd. Plant	PLANT	0.12		1.48	ESTIMATED
Yangon	16.78341	96.12694	Myanmar Economic Corporation	Cyclical, Seasonal	Corporate Office	OFFICE				
Bago	19.46808	96.38829	Naypyidaw Development Committee	Cyclical, Seasonal	Lewe Naypyidaw Plant	PLANT	0.15	CEM I 52.5	1.85	ESTIMATED
Yangon	16.77097	96.15675	Shwe Taung	Cyclical, Seasonal	Corporate Office	OFFICE				
Mandalay	21.95969	96.10833	Shwe Taung/ Apache Cement	Cyclical, Seasonal	Mandalay Office	OFFICE				
Mandalay	20.8672	96.39083	Shwe Taung/ Apache Cement	Cyclical, Seasonal	Pyi Nyaung Plant	PLANT	0.5	CEM I	6.15	ESTIMATED
Yangon	16.80584	96.17187	Shwe Taung/ Apache Cement	Cyclical, Seasonal	Head Office	OFFICE				
Yangon	16.80834	96.19501	Shwe Taung/ High Tech Concrete Co. Ltd.	Cyclical, Seasonal	Head Office	OFFICE				

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Qual-ity	Electric Re-quirements (MW)	Electric Re-quirement Source
Mandalay	21.6	96.2568	Sinminn Cement Industry Co. Ltd.	Cyclical, Seasonal	Kyaukse Ce-ment Plant	PLANT	0.84	CEM I	10.33	ESTIMATED
Mandalay	21.97328	96.10465	Sinminn Cement Industry Co. Ltd.	Cyclical, Seasonal	Corporate Office	OFFICE				
Mandalay	21.26929	95.44368	Tee Kyit Cement	Cyclical, Seasonal	Tee Kyit Ce-ment Plant	PLANT	0.002			
Ayeyarwaddy	18.30653	95.18559	The Republic of the Union of My-anmar, Ministry of Industries	Cyclical, Seasonal	No. (32) Heavy In-dustry (Kyangin)	PLANT	0.48	CEM I	5.90	ESTIMATED
Mandalay	21.59812	96.22703	The Republic of the Union of My-anmar, Ministry of Industries	Cyclical, Seasonal	No. (33) Heavy Industry (Kyaukse)	PLANT	0.15	CEM I	1.85	ESTIMATED
Bago	19.8202	96.14021	The Republic of the Union of My-anmar, Ministry of Industries	Cyclical, Seasonal	Ministry of Industries No. 2	OFFICE				
Magway	19.30701	95.18027	The Republic of the Union of My-anmar, Ministry of Industries	Cyclical, Seasonal	No. (31) Heavy Industry (Thayet)	PLANT	0.36	CEM I	4.43	ESTIMATED
Yangon	16.7698	96.1815	Union of Myan-mar Economic Holdings Ltd.	Cyclical, Seasonal	Head Office	OFFICE				
Yangon	21.58703	96.20809	Union of Myan-mar Economic Holdings Ltd.	Cyclical, Seasonal	Kyaukse Cement Plant	PLANT	0.21		2.58	ESTIMATED
Mandalay	20.8626	96.0514	Yangon City Development Committee	Cyclical, Seasonal	Thazi Cement Plant	PLANT	0.18		2.24	ESTIMATED
Yangon	16.77513	96.1599	Yangon City Development Committee	Cyclical, Seasonal	Head Office	OFFICE				

Table A6. Materials database – Bangladesh – concrete (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (cuft/mo)	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.914625	90.320852	ABC Ltd.	Regular	Ashulia Plant	PLANT	200000	0.30	ESTIMATE
Dhaka	24.101307	90.432724	ABC Ltd.	Regular	Rajendrapur Plant	PLANT	150000	0.30	ESTIMATE
Dhaka	23.793821	90.406009	ABC Ltd.	Regular	Corporate Office	OFFICE			
Dhaka	23.748983	90.39237	Abdul Monem Ltd.	Regular	Corporate Head Office	OFFICE	75000		ESTIMATE
Dhaka	23.89416667	90.33222222	Advanced Development and Technology Ltd.	Regular	Ashulia Plant	PLANT	734545.14	0.30	ESTIMATE
Dhaka	23.798469	90.413386	Advanced Development and Technology Ltd.	Regular	Headquarters	OFFICE			
Dhaka	23.62514	90.514675	AKIJ Cement	Regular	Plant	PLANT	650000	0.30	ESTIMATE
Dhaka	23.747045	90.370401	Amin Mohammad Group	Regular	Corporate Office	OFFICE			
Dhaka	23.93975	90.283129	Amin Mohammad Group	Regular	Factory	PLANT		0.30	ESTIMATE
Dhaka	23.760744	90.355663	Bangladesh Development and Consultants Ltd.	Regular	Office	OFFICE			
Dhaka	23.780598	90.416252	Bestec Group	Regular	Corporate Office	OFFICE			
Dhaka	23.788701	90.536858	Bestec Group	Regular	Factory	PLANT		0.30	ESTIMATE
Dhaka	23.794999	90.413087	Concord Ready Mix & Concrete Products Ltd.	Regular	Corporate Head Office	OFFICE			
Dhaka	23.760093	90.390707	Concord Ready Mix & Concrete Products Ltd.	Regular	Tejgaon Unit	PLANT	200000	0.30	ESTIMATE
Dhaka	23.765854	90.358284	Concord Ready Mix & Concrete Products Ltd.	Regular	Mohammadpur Unit	PLANT	200000	0.30	ESTIMATE

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (cuft/mo)	Electric Requirements (MW)	Electric Requirement Source
Dhaka	24.028017	90.38497	Concord Ready Mix & Concrete Products Ltd.	Regular	Shalna Unit	PLANT	200000	0.30	ESTIMATE
Dhaka	23.610509	90.605489	Concord Ready Mix & Concrete Products Ltd.	Regular	Tetuitola Concrete Block Unit	PLANT	200000	0.30	ESTIMATE
Dhaka	23.542134	90.531423	Concord Ready Mix & Concrete Products Ltd.	Regular	Concrete Load Bearing Products	PLANT	200000	0.30	ESTIMATE
Dhaka	23.610509	90.605489	Concord Ready Mix & Concrete Products Ltd.	Regular	Roof Tile Unit	PLANT	200000	0.30	ESTIMATE
Dhaka	24.028017	90.38497	Concord Ready Mix & Concrete Products Ltd.	Regular	Tiles Unit	PLANT	200000	0.30	ESTIMATE
Dhaka	23.878217	90.347768	Crown Cement Concrete and Building Products Ltd.	Regular	Factory	PLANT		0.30	ESTIMATE
Dhaka	23.769689	90.390029	GBB (Gulbox Bhuiyan Ltd.)	Regular	Corporate Office	OFFICE			
Dhaka	23.769689	90.390029	GBB (Gulbox Bhuiyan Ltd.)	Regular	Plant	PLANT	25000	0.30	ESTIMATE
Dhaka	23.7732883	90.3416276	Mir Concrete Products Ltd.	Regular	Gabtoli Plant	PLANT		0.30	ESTIMATE
Dhaka	23.754107	90.374781	Mir Concrete Products Ltd.	Regular	Corporate Office	OFFICE			
Dhaka	23.729287	90.415879	Navana Construction Ltd.	Regular	Registered Office	OFFICE			
Dhaka	23.770727	90.41088	Navana Construction Ltd.	Regular	Office	OFFICE			
Dhaka	23.743741	90.383472	Navana Construction Ltd.	Regular	Head Office	OFFICE	150000	0.30	ESTIMATE
Dhaka	23.774184	90.340984	NDE Ready Mix Concrete	Regular	Factory	PLANT	2387272	0.30	ESTIMATE
Dhaka	23.772908	90.413323	NDE Ready Mix Concrete	Regular	Corporate Head Office	OFFICE			

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (cuft/mo)	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.937523	90.286316	SEL Ready Mix Concrete	Regular	Plant	PLANT		0.30	ESTIMATE
Dhaka	23.822075	90.365334	Sena Kalyan Sangstha	Regular	Batching Plant	PLANT	214242.33	0.30	ESTIMATE
Dhaka	23.77799	90.344157	Shah Cement	Regular	Gabtoli Plant	PLANT	200000	0.30	ESTIMATE
Dhaka	23.911427	90.389174	Shah Cement	Regular	Tongi Plant	PLANT	200000	0.30	ESTIMATE
Dhaka	23.737345	90.408344	Toma Group	Regular	Corporate Office	OFFICE	84166.63		
Dhaka	23.777862	90.373418	Virtual	Regular	Corporate Office	OFFICE			

Table A7. Materials database – Bangladesh – iron (ERDC-CERL).

City	Latitude	Longitude	Preci-sion	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Chittagong	21.41619	91.98332	A		Regular	Bangladesh Heavy Minerals	DEPOSIT			

Table A8. Materials database – India – iron (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Bihar	24.9992	86.0002	A		Regular	Chirla	DEPOSIT			
Chhattisgarh	21.585061	81.702939	A	Alliance Integrated Metallics Ltd.	Regular	Sponge Iron Plant	PLANT	0.5		
Chhattisgarh	22.014354	83.402977	A	Anjani Steel Ltd.	Regular	Sponge Iron Plant	PLANT	0.102	12	PUBLISHED
Chhattisgarh	21.369973	81.684679	S	Godawari Power and Is-pat Ltd.	Regular	Sponge Iron Plant	PLANT	0.495		

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Chhattisgarh	21.293755	81.615774	S	Goel Group	Regular	Shri Bajrang Power and Ispat Ltd.	PLANT	0.128		
Chhattisgarh	21.88716	83.509233	A	Ind Synergy Ltd.	Regular	Sponge Iron Plant	PLANT	0.3		
Chhattisgarh	21.195201	81.209784	S	Jai Balaji Steel Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT	0.12		
Chhattisgarh	21.354942	81.672034	S	Jayaswal Neco Ltd.	Regular	Sponge Iron Plant	PLANT	0.255		
Chhattisgarh	21.93083333	83.34277778	S	Jindal Steel and Power Ltd.	Regular	Sponge Iron Plant	PLANT	1.32	894	PUBLISHED
Chhattisgarh	21.251376	81.62969	S	Monnet Group	Regular	Registered Office	OFFICE			
Chhattisgarh	21.243864	81.770947	S	Monnet Group	Regular	Monnet Ispat and Power Ltd.	PLANT	0.5		
Chhattisgarh	21.226538	81.773203	S	Monnet Group	Regular	Monnet Ispat and Power Ltd.	PLANT	0.3		
Chhattisgarh	21.878179	83.554968	A	MSP Steel and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.192		
Chhattisgarh	21.897398	83.394954	S	MSP Steel and Power Ltd.	Regular	Corporate Office	OFFICE			
Chhattisgarh	22.021991	83.380209	S	Nalwa Steel and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.198		
Chhattisgarh	18.7000008	81.25	A	National Mineral Development Corp. Ltd.	Regular	Mine at Bailadila	DEPOSIT	9		
Chhattisgarh	20.47959	80.98032	A		Regular	Kauchar Deposit	DEPOSIT			
Chhattisgarh	18.60806	81.24201	A		Regular	Bailadila No. 14	DEPOSIT			
Chhattisgarh	20.69957	80.63033	A		Regular	Kankar	DEPOSIT			
Chhattisgarh	18.61643	81.23364	A		Regular	Bailadila No. 14 Mine	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Chhattisgarh	18.68308	81.21698	A		Regular	Bailadila No. 11-C Mine	DEPOSIT			
Chhattisgarh	18.68308	81.20031	A		Regular	Bailadila No. 5 Mine	DEPOSIT			
Chhattisgarh	18.69585	81.19501	A		Regular	Bailadila No. 5	DEPOSIT			
Chhattisgarh	18.7000008	81.4667	A		Regular	Bailadila	DEPOSIT			
Chhattisgarh	21.88694444	82.04861111	S	Nova Iron and Steel	Regular	Sponge Iron Plant	PLANT	0.15		
Chhattisgarh	21.262881	81.614732	S	Prakash Industries Ltd.	Regular	Corporate Office	OFFICE			
Chhattisgarh	22.0323	82.651906	A	Prakash Industries Ltd.	Regular	Steel and Power Complex	PLANT	0.45		
Chhattisgarh	21.365716	81.681588	S	Sarda Energy and Minerals Ltd.	Regular	Works	PLANT	0.21		
Chhattisgarh	21.365716	81.681588	S	Sarda Energy and Minerals Ltd.	Regular	Head Office	OFFICE			
Chhattisgarh	21.908255	83.390436	A	Sarda Energy and Minerals Ltd.	Regular	Raigarh Office	OFFICE			
Chhattisgarh	21.95277778	83.47638889	S	Shiv Shakti Steel Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT	0.1		
Chhattisgarh	21.254911	81.651966	A	Shiva Group	Regular	API Ispat Power-tech Pvt. Ltd.	PLANT	0.105		
Chhattisgarh	21.252696	81.667876	S	Singhal Enter-prises Pvt. Ltd.	Regular	Corporate Office	OFFICE			
Chhattisgarh	21.252696	81.667876	A	Singhal Enter-prises Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT	0.194		
Chhattisgarh	21.39111111	81.64666667	S	SKS Ispat Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT	0.27	85	PUBLISHED
Chhattisgarh	21.277809	81.601488	S	SKS Ispat Pvt. Ltd.	Regular	Corporate Office	OFFICE			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Chhattisgarh	21.19952	81.28031	A	Steel Authority of India Ltd.	Regular	Dhalli-Rajhara	DEPOSIT			
Chhattisgarh	21.1800003	81.28	A	Steel Authority of India Ltd.	Regular	Mine	DEPOSIT	7		
Chhattisgarh	21.249779	81.635231	S	Sunil Ispat and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.105		
Chhattisgarh	21.255017	81.646215	A	Sunil Ispat and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.115		
Chhattisgarh	21.257447	81.561251	A	Tirupati Steel	Regular	Head Office	OFFICE			
Chhattisgarh	21.189587	81.199811	S	Topworth Steel Pvt. Ltd.	Regular	Crest Steel and Power Ltd.	PLANT	0.115		
Chhattisgarh	21.188091	81.211992	S	Topworth Steel Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT			
Chhattisgarh	21.232994	81.658278	S	Vandana Global Ltd.	Regular	Corporate Office	OFFICE			
Chhattisgarh	21.251901	81.625084	A	Vandana Global Ltd.	Regular	Sponge Iron Plant	PLANT	0.216		
Jharkhand	22.802241	86.116655	A	Ashirwad Steels and Industries Ltd.	Regular	Sponge Iron Plant	PLANT			
Jharkhand	22.909736	86.074602	S	Bihar Sponge Iron Ltd.	Regular	Sponge Iron Plant	PLANT	0.21		
Jharkhand	22.13277	85.16688	A		Regular	Noamundi Mine	DEPOSIT			
Jharkhand	22.19943	85.4002	A		Regular	Jalamial Buru	DEPOSIT			
Jharkhand	22.19943	85.3302	A		Regular	Ajiti Buru Barai	DEPOSIT			
Jharkhand	22.15943	85.3602	A		Regular	Jiripai Buru Lower	DEPOSIT			
Jharkhand	22.17943	85.4002	A		Regular	Not Buru	DEPOSIT			
Jharkhand	22.21943	85.3602	A		Regular	Durbar	DEPOSIT			
Jharkhand	22.17943	85.3302	A		Regular	Duarguia Buru	DEPOSIT			
Jharkhand	22.24943	85.4002	A		Regular	Landrup Buru	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Jharkhand	22.25942	85.4102	A		Regular	Idri Buru	DEPOSIT			
Jharkhand	22.19943	85.3602	A		Regular	Baya Buru	DEPOSIT			
Jharkhand	22.17943	85.3302	A		Regular	Jiripai Buru Upper	DEPOSIT			
Jharkhand	22.14943	85.3502	A		Regular	Tatiba Buru Lower	DEPOSIT			
Jharkhand	22.27942	85.28021	A		Regular	Bogardui Buru	DEPOSIT			
Jharkhand	22.22943	85.4002	A		Regular	Jaridasouth Area	DEPOSIT			
Jharkhand	22.20943	85.28021	A		Regular	Dirisium	DEPOSIT			
Jharkhand	22.30942	85.3602	A		Regular	Pansira Buru	DEPOSIT			
Jharkhand	22.16613	85.5002	A		Regular	Tata	DEPOSIT			
Jharkhand	22.27942	85.3602	A		Regular	Banalata	DEPOSIT			
Jharkhand	22.24943	85.3802	A		Regular	Jarida Buru	DEPOSIT			
Jharkhand	22.09944	85.3302	A		Regular	Bolani	DEPOSIT			
Jharkhand	22.25942	85.21021	A		Regular	Marang Ponga	DEPOSIT			
Jharkhand	22.18943	85.20021	A		Regular	Ajiti Burueast	DEPOSIT			
Jharkhand	22.15943	85.3502	A		Regular	Tatiba Buru Upper	DEPOSIT			
Jharkhand	22.20943	85.4002	A		Regular	Jiling Buru	DEPOSIT			
Jharkhand	22.5172	86.47207	A		Regular	Mosabani-Badia Area	DEPOSIT			
Jharkhand	22.20943	85.25021	A		Regular	Hokolata	DEPOSIT			
Jharkhand	22.18943	85.5252	A		Regular	Hatu Gutu Buru-Noamundi Mine	DEPOSIT			
Jharkhand	22.17943	85.5402	A		Regular	Bond Buru-Noamundi Mine	DEPOSIT			
Jharkhand	22.15943	85.5002	A		Regular	Charipat Buru-Noamundi Mine	DEPOSIT			
Jharkhand	22.15943	85.5302	A		Regular	Pachri Buru-Noamundi Mine	DEPOSIT			
Jharkhand	22.12944	85.5302	A		Regular	Lagirda Buru-Noamundi Mine	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Jharkhand	22.19943	85.5002	A		Regular	Baljori-Noamundi Mine	DEPOSIT			
Jharkhand	22.14943	85.5502	A		Regular	Kotamati Buru Keonjhar Side-Noa	DEPOSIT			
Jharkhand	22.13944	85.5002	A		Regular	Bai Buru-Noamundi Mine	DEPOSIT			
Jharkhand	22.14943	85.5502	A		Regular	Kotamati Burusouth-Noamundi Mine	DEPOSIT			
Jharkhand	22.15943	85.4102	A		Regular	Uli Buru-Bilkundi	DEPOSIT			
Jharkhand	23.373144	85.324094	A	Shiva Group	Regular	Bhuwania Associ-ates Pvt. Ltd.	PLANT	0.073		
Jharkhand	22.7999992	86.09	A	Steel Authority of India Ltd.	Regular	Mine in Singhbhum District	DEPOSIT	2.5		
Jharkhand	22.7999992	86.09	A	Steel Authority of India Ltd.	Regular	Mine in Singhbhum District	DEPOSIT	3.5		
Jharkhand	22.218722	85.355946	A	Steel Authority of India Ltd.	Regular	Gua Mines	DEPOSIT			
Jharkhand	22.06611	85.26688	S	Steel Authority of India Ltd.	Regular	Kiriburu Mine	DEPOSIT			
Jharkhand	22.072453	85.26977	S	Steel Authority of India Ltd.	Regular	Meghahatuburu Iron Ore Mines	DEPOSIT			
Jharkhand	22.374262	85.195618	A	Steel Authority of India Ltd.	Regular	Manoharpur (Chiria) Mine	DEPOSIT			
Jharkhand	22.1333008	85.3167	A	Steel Authority of India Ltd.	Regular	Bolani	DEPOSIT			
Jharkhand	22.7999992	86.09	A	Tata Iron and Steel Co. Ltd.	Regular	Mine in Singhbhum District	DEPOSIT	3.5		
Jharkhand	23.748838	86.151416	A	Zoom Vallabh Steels Ltd.	Regular	Sponge Iron Plant	PLANT	0.12		

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Orissa	20.51833333	85.73027778	S	Aarti Steels Ltd.	Regular	Sponge Iron Plant	PLANT	0.18	90	PUBLISHED
Orissa	21.843123	83.98113	S	Action Ispat and Power Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT	0.25		
Orissa	22.30826	84.764113	S	Adhunik Group	Regular	Adhunik Metaliks Ltd.	PLANT	0.18		
Orissa	22.112995	85.374732	A	Beekay Steel and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.105		
Orissa	20.284114	85.815332	S	Bhushan Steel and Strips Ltd.	Regular	Sponge Iron Plant	PLANT	0.3		
Orissa	22.049333	85.166117	A	Deepak Steel and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.144		
Orissa	21.91888889	85.41111111	S	Essel Mining and Industries Ltd.	Regular	Jilling Langalota Iron Mine	DEPOSIT			
Orissa	21.91277778	84.02944444	S	Jain Steel and Power Ltd.	Regular	Sponge Iron Plant	PLANT	0.11	8	PUBLISHED
Orissa	20.96833333	86.04916667	A	Mesco Steel	Regular	Sponge Iron Plant	PLANT			
Orissa	20.773683	85.33883	S	MGM Group	Regular	MGM Steels Ltd.	PLANT	0.1		
Orissa	20.255021	85.826279	S	MGM Group	Regular	Corporate Office	OFFICE			
Orissa	22.07444	85.2802	A		Regular	Maghahata Buru	DEPOSIT			
Orissa	21.90946	85.4002	A		Regular	South East of Palsa	DEPOSIT			
Orissa	21.8715746	85.149695	A		Regular	Barsua	DEPOSIT			
Orissa	21.80946	85.3602	A		Regular	North of Mitihurda	DEPOSIT			
Orissa	21.86946	85.19021	A		Regular	Unagarapora Pahar	DEPOSIT			
Orissa	21.92945	85.3602	A		Regular	Satkutnia Pahar	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Orissa	21.95945	85.3002	A		Regular	Guali-Godabudini	DEPOSIT			
Orissa	21.94945	85.4102	A		Regular	Kurband-Joruri	DEPOSIT			
Orissa	21.90861111	85.36416667	S		Regular	Mohanty Iron and Manganese Mine	DEPOSIT			
Orissa	22.04944	86.21018	A		Regular	Gorumakisani	DEPOSIT			
Orissa	21.9025	85.36722222	S		Regular	Prabodh Mo-hanty Iron Mine	DEPOSIT			
Orissa	21.90946	85.3702	A		Regular	Gurda-Gonua	DEPOSIT			
Orissa	21.90833333	85.35833333	S		Regular	Mandajoda Iron and Manganese Mine	DEPOSIT			
Orissa	21.92945	85.3902	A		Regular	Northwest of Joribar	DEPOSIT			
Orissa	21.91945	85.17021	A		Regular	Samlaibar	DEPOSIT			
Orissa	21.77947	85.10021	A		Regular	Kandadhar Pahar	DEPOSIT			
Orissa	21.99946	85.23021	A		Regular	Majurnacha	DEPOSIT			
Orissa	21.94945	85.3802	A		Regular	Northwest of Satkutnia	DEPOSIT			
Orissa	21.79947	85.25021	A		Regular	Balia Pahar-Badamgarh	DEPOSIT			
Orissa	21.92138889	85.3925	S		Regular	Serajuddin Mines	DEPOSIT			
Orissa	21.82946	85.4002	A		Regular	Chrisai-Loiaboga	DEPOSIT			
Orissa	21.79947	85.23021	A		Regular	Badamgarh	DEPOSIT			
Orissa	21.95945	85.3902	A		Regular	Dale Pahar-North of Kurband	DEPOSIT			
Orissa	21.95945	85.4302	A		Regular	Jilling Pahar	DEPOSIT			
Orissa	21.89946	85.24021	A		Regular	Kassira-Rengerbera	DEPOSIT			
Orissa	21.85946	85.4302	A		Regular	Maha Parbat	DEPOSIT			
Orissa	21.74947	86.16018	A		Regular	Badam Pahar	DEPOSIT			
Orissa	21.89946	85.25021	A		Regular	Jamda-Koira Valley	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Orissa	21.89946	85.4002	A		Regular	Ranga Parbat	DEPOSIT			
Orissa	21.77947	85.20021	A		Regular	Mankarmacha Hill	DEPOSIT			
Orissa	22.07944	85.3602	A		Regular	Jhargaon	DEPOSIT			
Orissa	21.79947	85.3602	A		Regular	Kesijoda	DEPOSIT			
Orissa	20.82955	86.33018	A		Regular	Kansa	DEPOSIT			
Orissa	21.80946	85.3602	A		Regular	South of Mitihurda	DEPOSIT			
Orissa	22.04944	85.4502	A		Regular	Bara Parbat-Joda East Mine	DEPOSIT			
Orissa	22.09944	85.3302	A		Regular	Bolani	DEPOSIT			
Orissa	22.02944	85.4002	S		Regular	Durga Parbat	DEPOSIT			
Orissa	22.09944	85.4302	A		Regular	Thakurani Mine: West Thakuranino	DEPOSIT			
Orissa	21.89946	85.23021	A		Regular	Khajardi	DEPOSIT			
Orissa	21.95945	85.4302	S		Regular	Langalota	DEPOSIT			
Orissa	21.84946	85.3602	A		Regular	East of Mitihurda	DEPOSIT			
Orissa	21.77947	85.16021	A		Regular	Raisua Resi-Jhubba Dinakora	DEPOSIT			
Orissa	21.94945	85.20021	A		Regular	Karspani Pahar	DEPOSIT			
Orissa	20.82955	86.33018	A		Regular	Daiteri	DEPOSIT			
Orissa	22.04944	85.3502	A		Regular	Sidamat Parbat	DEPOSIT			
Orissa	21.74947	86.45017	A		Regular	Kumdabadi and Bandgaon	DEPOSIT			
Orissa	21.77447	85.15021	A		Regular	Saraikela Roatha-Raisua Resi	DEPOSIT			
Orissa	21.82946	85.2802	A		Regular	Malang Toli	DEPOSIT			
Orissa	21.77947	85.3002	A		Regular	Balia Pahar	DEPOSIT			
Orissa	21.73947	85.13021	A		Regular	Kumritar Pahar-Cheliatoka	DEPOSIT			
Orissa	22.11614	85.3502	A		Regular	Barbill Mine	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Orissa	21.90946	85.4002	A		Regular	North of Palsa	DEPOSIT			
Orissa	21.94945	86.16018	A		Regular	Sulaipatokampad	DEPOSIT			
Orissa	21.85946	85.3902	A		Regular	Diring Buru	DEPOSIT			
Orissa	21.80946	85.21021	A		Regular	Jhubka	DEPOSIT			
Orissa	22.07944	85.3002	A		Regular	Kiri Buru	DEPOSIT			
Orissa	21.94945	85.4002	A		Regular	West of Kurband-Northeast of Satk	DEPOSIT			
Orissa	21.95945	85.4002	A		Regular	West of Banspani-North of Johohur	DEPOSIT			
Orissa	19.44968	83.15026	A		Regular	Manjimali	DEPOSIT			
Orissa	20.49958	85.00022	A		Regular	Daitari Mine	DEPOSIT			
Orissa	22.08277	85.33353	A		Regular	Bolani Mine	DEPOSIT			
Orissa	22.01612	85.43353	S		Regular	Joda Mine	DEPOSIT			
Orissa	22.07444	85.4102	A		Regular	Raikora-Borita	DEPOSIT			
Orissa	21.75947	85.14021	A		Regular	Kumritar Pahar	DEPOSIT			
Orissa	22.05944	85.4002	A		Regular	Badraeai	DEPOSIT			
Orissa	21.99946	85.4302	S		Regular	Banspani Pahar-Joda East Mine	DEPOSIT			
Orissa	22.04944	85.4102	A		Regular	Kela Parbat	DEPOSIT			
Orissa	21.79947	85.20021	A		Regular	Badamgarh-Mankarmacha	DEPOSIT			
Orissa	20.82955	86.33018	A		Regular	Bamanipal and Tomka	DEPOSIT			
Orissa	21.92445	85.4002	A		Regular	Southeast of Joribar	DEPOSIT			
Orissa	22.14943	85.5502	A		Regular	Kotamati Burunorth-Noamundi Mine	DEPOSIT			
Orissa	22.00945	85.4102	S		Regular	Surjat Parbat	DEPOSIT			
Orissa	21.90946	85.4302	S		Regular	Boradha-Kunipas	DEPOSIT			
Orissa	21.9475	85.43361111	S		Regular	T B Lal Jajang Mine	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Orissa	21.96972222	85.44611111	S		Regular	S C Padhi Gurubeda Mine	DEPOSIT			
Orissa	21.96861111	85.40805556	S		Regular	Khondobond Iron Mine	DEPOSIT			
Orissa	21.96138889	85.43194444	S		Regular	H G Pandya Mine	DEPOSIT			
Orissa	22.00945	85.4002	A		Regular	Baliathori Parbat	DEPOSIT			
Orissa	21.97666667	85.44527778	A		Regular	S C Padhi Banspari Mine	DEPOSIT			
Orissa	22.02944	85.4602	A		Regular	Kundrupani-Churr Malda	DEPOSIT			
Orissa	21.94945	86.43017	A		Regular	Mayurbanj Area: Kaduani, Kumhardh	DEPOSIT			
Orissa	21.88888889	85.36138889	S		Regular	B C Dagra, Dalita Iron and Manganese	DEPOSIT			
Orissa	21.80946	85.3602	A		Regular	Southeast of Mitihurda	DEPOSIT			
Orissa	21.99946	86.0002	A		Regular	Singhbhum-Mayurbhanj District	DEPOSIT			
Orissa	22.0832996	85.2833	A		Regular	Kiriburu	DEPOSIT			
Orissa	21.8075	85.56805556	S		Regular	Sponge Iron Plant	PLANT			
Orissa	22.188017	84.580082	A	OCL Iron and Steel Ltd.	Regular	Registered Office	OFFICE			
Orissa	22.213088	84.551887	S	OCL Iron and Steel Ltd.	Regular	Works	PLANT	0.12	18	PUBLISHED
Orissa	20.296109	85.824551	S	Orissa Sponge Iron and Steel Ltd.	Regular	Corporate Office	OFFICE			
Orissa	21.805	85.56388889	S	Orissa Sponge Iron and Steel Ltd.	Regular	Sponge Iron Plant	PLANT	0.25	40	PUBLISHED
Orissa	21.92945	85.4002	S	Patnaik Minerals Pvt. Ltd.	Regular	Jaribahal Iron Mine	DEPOSIT			
Orissa	21.884996	85.3785217	S	Rungta Mines Ltd.	Regular	Siljora Kalimati Mn. Mines	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Orissa	22.123512	84.041816	A	Rungta Mines Ltd.	Regular	Sponge Iron Plant	PLANT	0.33		
Orissa	20.651015	85.595846	A	Scaw Industries Pvt. Ltd.	Regular	Sponge Iron Plant	PLANT	0.1		
Orissa	21.683792	85.4358	A	Sree Metaliks Ltd.	Regular	Head Office	OFFICE			
Orissa	21.683792	85.4358	S	Sree Metaliks Ltd.	Regular	Sponge Iron Plant	PLANT	0.174	28	PUBLISHED
Orissa	21.85305556	85.12555556	S	Steel Authority of India Ltd.	Regular	Barsua	DEPOSIT			
Orissa	21.84946	85.15021	A	Steel Authority of India Ltd.	Regular	Barsuan Iron Mine	DEPOSIT			
Orissa	21.969493	85.223126	A	Steel Authority of India Ltd.	Regular	Kalta	DEPOSIT			
Orissa	21.6900005	85.52	A	Steel Authority of India Ltd.	Regular	Mine in Kendujhar District	DEPOSIT	3		
Orissa	21.9316396	85.3804659	S	Tata Iron and Steel Co. Ltd.	Regular	Khondbond Mine	DEPOSIT			
Orissa	21.6900005	85.52	A	Tata Iron and Steel Co. Ltd.	Regular	Mine at Kendujhar District	DEPOSIT	2		
Orissa	22.019208	85.406811	A	Tata Sponge Iron	Regular	Registered Office	OFFICE			
Orissa	22.055822	85.46567	S	Tata Sponge Iron	Regular	Sponge Iron Plant	PLANT	0.39		
Orissa	20.943447	86.061403	S	Visa Steel	Regular	Sponge Iron Plant	PLANT	0.3	75	PUBLISHED
West Bengal	22.539904	88.355113	S	Adhunik Metaliks Ltd.	Regular	Corporate Office	OFFICE			
West Bengal	22.567702	88.350917	S	Ashirwad Steels and Industries Ltd.	Regular	Corporate Office	OFFICE			
West Bengal	22.539922	88.355051	S	Beekay Steel and Power Ltd.	Regular	Corporate Office	OFFICE			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
West Bengal	22.551723	88.352488	S	Bhushan Group	Regular	Corporate Office	OFFICE			
West Bengal	23.611124	87.147394	S	Jai Balaji Sponge Ltd.	Regular	Sponge Iron Plant	PLANT	0.105		
West Bengal	23.41599	86.91683	A		Regular	Shaltora Area	DEPOSIT			
West Bengal	23.7493	86.86016	A		Regular	Kulti-Raniganj	DEPOSIT			
West Bengal	24.69611111	87.09416667	S		Regular	Damodar Sponge Iron Factory	PLANT			
West Bengal	22.537937	88.350638	S	Orissa Sponge Iron and Steel Ltd.	Regular	Corporate Office	OFFICE			
West Bengal	22.545119	88.353639	S	Rungta Mines Ltd.	Regular	Corporate Office	OFFICE			
West Bengal	22.567036	88.353873	S	Shyam Group	Regular	Registered Office	OFFICE			
West Bengal	22.568107	88.355991	S	Shyam Group	Regular	Corporate Office	OFFICE			
West Bengal	23.508663	87.282936	A	Shyam Group	Regular	Sponge Iron Plant	PLANT	0.1		
West Bengal	23.513214	87.331602	S	SPS Group	Regular	Re-rolling Mill/ Sponge Iron Plant	PLANT	0.6		
West Bengal	22.541317	88.356191	S	SPS Group	Regular	Corporate Office	OFFICE			
West Bengal	22.545075	88.35502	S	Sree Metaliks Ltd.	Regular	Registered Office	OFFICE			
West Bengal	22.555863	88.365008	S	Sunil Ispat and Power Ltd.	Regular	Corporate Office	OFFICE			
West Bengal	23.52388889	87.13222222	S	Tirupati Steel	Regular	Sponge Iron Plant	PLANT			

Table A9. Materials database – Myanmar – iron (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Bago	18.0329	96.89989	A		Regular	Tungoo Deposit	DEPOSIT			

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Electric Requirements (MW)	Electric Requirement Source
Mandalay	21.98611111	96.40666667	S	Republic of the Union of Myanmar, Ministry of Industry	Regular	Sponge Iron Plant	PLANT	0.45		
Shan	20.83285	97.33318	A		Regular	Hopong Mine	DEPOSIT			
Shan	21.83276	97.71657	A		Regular	Lai Twarge Mine	DEPOSIT			
Shan	22.13273	96.6332	A		Regular	Wetwun Area	DEPOSIT			
Shan	21.94945	96.4166	A		Regular	Twinnge Deposit	DEPOSIT			
Shan	20.91624	96.88319	A		Regular	Pang Pet Deposits	DEPOSIT			
Shan	22.83267	97.66657	A		Regular	Manmaklang /Nam Phat Mines	DEPOSIT			
Shan	23.21604	97.28318	A		Regular	Kunghka Mine	DEPOSIT			

Table A10. Materials database – Bangladesh – limestone (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Rajshahi	24.793954	88.931438		Regular	Paranagar Naogaon Mine	DEPOSIT	
Rajshahi	25.10212	89.031188		Regular	Joypurhat Mine	DEPOSIT	100
Rangpur	25.123927	88.924741		Regular	Jahanpur Naogaon Mine	DEPOSIT	
Sylhet	24.847888	91.235116		Regular	Bagalibazar Mine	DEPOSIT	17
Sylhet	25.067205	91.407288		Regular	Lalghat Mine	DEPOSIT	12.9
Sylhet	25.201605	91.199592		Regular	Takerghat Mine	DEPOSIT	12.9

Table A11. Materials database – India – limestone (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	20.425	81.52083333		Regular		DEPOSIT	
Chhattisgarh	20.79306	81.05833		Regular	Chattisgarh Basin / Lohara Area	DEPOSIT	
Chhattisgarh	21.2163889	81.75		Regular		DEPOSIT	143.83
Chhattisgarh	21.3416667	81.75		Regular		DEPOSIT	48.25
Chhattisgarh	21.3583333	82.04166667		Regular		DEPOSIT	37.881
Chhattisgarh	21.3770833	82.00833333		Regular		DEPOSIT	10.02
Chhattisgarh	21.3958333	81.76111111		Regular		DEPOSIT	70.82
Chhattisgarh	21.4033333	81.79763889		Regular		DEPOSIT	56.89
Chhattisgarh	21.4113889	81.81611111		Regular		DEPOSIT	5.925
Chhattisgarh	21.45	81.87777778		Regular		DEPOSIT	13.6
Chhattisgarh	21.4606944	81.81055556		Regular		DEPOSIT	39.66
Chhattisgarh	21.4958333	81.75		Regular		DEPOSIT	47.95
Chhattisgarh	21.5016667	81.88930556		Regular		DEPOSIT	173.44
Chhattisgarh	21.5025	81.76388889		Regular		DEPOSIT	33.65
Chhattisgarh	21.5493056	82.03458333		Regular		DEPOSIT	162.51
Chhattisgarh	21.55	81.98333333		Regular		DEPOSIT	206.787
Chhattisgarh	21.56	81.9875		Regular		DEPOSIT	171.4
Chhattisgarh	21.5652778	81.99444444	Ultratech Cement	Regular		DEPOSIT	
Chhattisgarh	21.5708333	81.97916667		Regular		DEPOSIT	1.829
Chhattisgarh	21.5708333	81.99166667		Regular		DEPOSIT	79.1
Chhattisgarh	21.5833333	81.91666667		Regular		DEPOSIT	146.288
Chhattisgarh	21.5854167	81.92916667		Regular		DEPOSIT	0.842

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	21.6	82.07916667		Regular		DEPOSIT	518.65
Chhattisgarh	21.6041667	81.96666667		Regular		DEPOSIT	13.83
Chhattisgarh	21.6125	81.975		Regular		DEPOSIT	10.03
Chhattisgarh	21.6166667	82.03472222		Regular		DEPOSIT	86.88
Chhattisgarh	21.6354167	81.95		Regular		DEPOSIT	0.908
Chhattisgarh	21.65375	82.05777778		Regular		DEPOSIT	342.952
Chhattisgarh	21.6579167	82.10416667		Regular		DEPOSIT	484.736
Chhattisgarh	21.66875	81.48333333		Regular		DEPOSIT	8.42
Chhattisgarh	21.6708333	82.10430556		Regular		DEPOSIT	335.15
Chhattisgarh	21.6729167	82.10055556		Regular		DEPOSIT	188.04
Chhattisgarh	21.6833333	82.64583333		Regular		DEPOSIT	517.74
Chhattisgarh	21.6854167	82.11666667		Regular		DEPOSIT	117.13
Chhattisgarh	21.7395833	82.20625		Regular		DEPOSIT	191
Chhattisgarh	21.75	82.28333333		Regular		DEPOSIT	
Chhattisgarh	21.7541667	82.38333333		Regular		DEPOSIT	48
Chhattisgarh	21.9586111	82.34166667	Arasmeta Limestone Mines	Regular		DEPOSIT	
Chhattisgarh	21.0833333	82.05		Regular		DEPOSIT	
Chhattisgarh	21.2166667	81.95		Regular		DEPOSIT	0.5
Chhattisgarh	21.25	81.8		Regular		DEPOSIT	0.75
Chhattisgarh	21.2333333	81.78333333		Regular		DEPOSIT	
Chhattisgarh	21.2	81.73333333		Regular		DEPOSIT	3
Chhattisgarh	21.4420833	81.24055556		Regular		DEPOSIT	101.04
Chhattisgarh	21.4020833	81.44791667		Regular		DEPOSIT	

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	22.1347222	81.42916667		Regular		DEPOSIT	1500
Chhattisgarh	21.4525	81.40861111		Regular		DEPOSIT	109.19
Chhattisgarh	21.4358333	81.39597222		Regular		DEPOSIT	45.57
Chhattisgarh	21.5208333	81.22916667		Regular		DEPOSIT	
Chhattisgarh	21.6180556	81.15194444		Regular		DEPOSIT	
Chhattisgarh	21.5619444	81.19861111		Regular		DEPOSIT	
Chhattisgarh	21.2138889	81.21527778		Regular		DEPOSIT	
Chhattisgarh	21.0977778	81.24583333		Regular		DEPOSIT	
Chhattisgarh	21.025	81.35833333		Regular		DEPOSIT	
Chhattisgarh	21.0958333	81.33055556		Regular		DEPOSIT	
Chhattisgarh	21.1069444	81.31805556		Regular		DEPOSIT	
Chhattisgarh	21.2333333	81.29916667		Regular		DEPOSIT	
Chhattisgarh	21.9180556	81.57083333		Regular		DEPOSIT	
Chhattisgarh	21.3383333	81.56861111		Regular		DEPOSIT	
Chhattisgarh	21.5208333	81.22916667		Regular		DEPOSIT	
Chhattisgarh	21.3958333	81.36666667		Regular		DEPOSIT	
Chhattisgarh	21.4333333	81.425		Regular		DEPOSIT	
Chhattisgarh	21.3958333	81.36666667		Regular		DEPOSIT	15
Chhattisgarh	21.3791667	81.3		Regular		DEPOSIT	
Chhattisgarh	21.3708333	81.30833333		Regular		DEPOSIT	
Chhattisgarh	21.4041667	81.34583333		Regular		DEPOSIT	
Chhattisgarh	21.4708333	81.34166667		Regular		DEPOSIT	
Chhattisgarh	21.45	81.35833333		Regular		DEPOSIT	

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	21.2125	81.075		Regular		DEPOSIT	
Chhattisgarh	21.3208333	81.07916667		Regular		DEPOSIT	
Chhattisgarh	21.3833333	81.275		Regular		DEPOSIT	
Chhattisgarh	22.375	81.16666667		Regular		DEPOSIT	31.419
Chhattisgarh	21.7777778	81.22152778		Regular		DEPOSIT	178.057
Chhattisgarh	22.1916667	81.14166667		Regular		DEPOSIT	
Chhattisgarh	21.7683333	81.21041667		Regular		DEPOSIT	23.769
Chhattisgarh	20.9638889	80.90694444		Regular		DEPOSIT	
Chhattisgarh	21.6214444	81.76466667		Regular		DEPOSIT	
Chhattisgarh	21.5979722	81.09091667		Regular		DEPOSIT	
Chhattisgarh	21.6670278	81.13877778		Regular		DEPOSIT	
Chhattisgarh	21.3608889	80.98294444		Regular		DEPOSIT	
Chhattisgarh	21.4281111	80.92305556		Regular		DEPOSIT	
Chhattisgarh	21.67275	80.90213889		Regular		DEPOSIT	
Chhattisgarh	21.5936111	81.85222222		Regular		DEPOSIT	
Chhattisgarh	21.5703056	80.84511111		Regular		DEPOSIT	0.1
Chhattisgarh	22.375	81.16666667		Regular		DEPOSIT	31.419
Chhattisgarh	21.7777778	81.22152778		Regular		DEPOSIT	150.355
Chhattisgarh	21.7972222	81.21111111		Regular		DEPOSIT	27.702
Chhattisgarh	22.1916667	81.29166667		Regular		DEPOSIT	
Chhattisgarh	21.7683333	81.21041667		Regular		DEPOSIT	23.769
Chhattisgarh	21.2866667	81.41305556		Regular		DEPOSIT	
Chhattisgarh	22.0763889	81.30027778		Regular		DEPOSIT	0.6

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	22.0377778	81.30666667		Regular		DEPOSIT	0.375
Chhattisgarh	22.2936111	81.53027778		Regular		DEPOSIT	0.075
Chhattisgarh	21.6666667	83.125		Regular		DEPOSIT	384.118
Chhattisgarh	21.5208333	83.15833333		Regular		DEPOSIT	12.3
Chhattisgarh	21.6166667	83.16666667		Regular		DEPOSIT	
Chhattisgarh	21.9416667	82.95833333		Regular		DEPOSIT	15.092
Chhattisgarh	21.5	83.16666667		Regular		DEPOSIT	
Chhattisgarh	21.5055556	83.15833333		Regular		DEPOSIT	
Chhattisgarh	21.6055556	83.13333333		Regular		DEPOSIT	
Chhattisgarh	21.6055556	83.15		Regular		DEPOSIT	
Chhattisgarh	21.625	83.13333333		Regular		DEPOSIT	
Chhattisgarh	21.6333333	83.1		Regular		DEPOSIT	
Chhattisgarh	21.6	21.11666667		Regular		DEPOSIT	
Chhattisgarh	21.6333333	83.06666667		Regular		DEPOSIT	
Chhattisgarh	21.6083333	83.05		Regular		DEPOSIT	
Chhattisgarh	21.625	83.06666667		Regular		DEPOSIT	
Chhattisgarh	21.65	83.18333333		Regular		DEPOSIT	
Chhattisgarh	21.6	82.95		Regular		DEPOSIT	
Chhattisgarh	21.6	82.95833333		Regular		DEPOSIT	
Chhattisgarh	21.5694444	83.16666667		Regular		DEPOSIT	
Chhattisgarh	21.6083333	83.43333333		Regular		DEPOSIT	
Chhattisgarh	21.6227778	57		Regular		DEPOSIT	
Chhattisgarh	19.25	81.875		Regular		DEPOSIT	72.65

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	19.2083333	81.95833333		Regular		DEPOSIT	7.8
Chhattisgarh	19.125	81.5		Regular		DEPOSIT	7.8
Chhattisgarh	18.9583333	81.53333333		Regular		DEPOSIT	48.55
Chhattisgarh	19.0145833	81.82083333		Regular		DEPOSIT	
Chhattisgarh	19.15	81.85069444		Regular		DEPOSIT	47.73
Chhattisgarh	19.1458333	81.80319444		Regular		DEPOSIT	44.93
Chhattisgarh	19.3968056	81.45833333		Regular		DEPOSIT	44.89
Chhattisgarh	19.0833333	81.84166667		Regular		DEPOSIT	45.98
Chhattisgarh	19.1333333	81.84166667		Regular		DEPOSIT	14.55
Chhattisgarh	19.4347222	81.83333333		Regular		DEPOSIT	21.22
Chhattisgarh	18.9645833	81.82402778		Regular		DEPOSIT	40
Chhattisgarh	18.95	81.825		Regular		DEPOSIT	19
Chhattisgarh	19.4186111	81.83333333		Regular		DEPOSIT	85.88
Chhattisgarh	19.13125	81.82722222		Regular		DEPOSIT	61.98
Chhattisgarh	18.875	81.91666667		Regular		DEPOSIT	3.64
Chhattisgarh	18.9583333	81.95833333		Regular		DEPOSIT	47.11
Chhattisgarh	18.9166667	81.875		Regular		DEPOSIT	4
Chhattisgarh	18.9583333	81.875		Regular		DEPOSIT	6.3
Chhattisgarh	20.9279167	56.125		Regular		DEPOSIT	176.29
Chhattisgarh	22.2625	81.84375		Regular		DEPOSIT	82.24
Chhattisgarh	22.2722222	81.49166667		Regular		DEPOSIT	6.311
Chhattisgarh	21.2326389	81.59166667		Regular		DEPOSIT	
Chhattisgarh	21.7916667	82.25416667		Regular		DEPOSIT	16.37

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	22.0416667	82.96111111		Regular		DEPOSIT	0.09
Chhattisgarh	21.9666667	82.79166667		Regular		DEPOSIT	0.072
Chhattisgarh	22	82.78333333		Regular		DEPOSIT	0.072
Chhattisgarh	22.0833333	82.63333333		Regular		DEPOSIT	13.5
Chhattisgarh	22.0561111	37.5		Regular		DEPOSIT	1.2
Chhattisgarh	21.8166667	82.65833333		Regular		DEPOSIT	3
Chhattisgarh	21.825	82.625		Regular		DEPOSIT	0.3
Chhattisgarh	21.8416667	82.60833333		Regular		DEPOSIT	0.131
Chhattisgarh	21.7833333	82.70833333		Regular		DEPOSIT	
Chhattisgarh	22.0833333	82.56666667		Regular		DEPOSIT	0.36
Chhattisgarh	22.05	82.575		Regular		DEPOSIT	
Chhattisgarh	22.0583333	82.54166667		Regular		DEPOSIT	
Chhattisgarh	22.0416667	82.49166667		Regular		DEPOSIT	
Chhattisgarh	22.0666667	82.26666667		Regular		DEPOSIT	
Chhattisgarh	21.85875	82.35138889		Regular		DEPOSIT	110.54
Chhattisgarh	21.9027778	82.51666667		Regular		DEPOSIT	85.75
Chhattisgarh	21.9504167	82.33333333		Regular		DEPOSIT	133.86
Chhattisgarh	21.8708333	82.55833333		Regular		DEPOSIT	3.67
Chhattisgarh	21.8520833	82.625		Regular		DEPOSIT	41
Chhattisgarh	21.8388889	82.63611111		Regular		DEPOSIT	9
Chhattisgarh	21.8597222	82.57027778		Regular		DEPOSIT	1
Chhattisgarh	22.3625	82.53333333		Regular		DEPOSIT	47
Chhattisgarh	21.9166667	82.5		Regular		DEPOSIT	37

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	21.5583333	82.54166667		Regular		DEPOSIT	
Jharkland	22.870003	85.451987		Regular	Singhbhum	DEPOSIT	192.98
Jharkland	23.34724	85.30621		Regular	Ranchi	DEPOSIT	192.98
Jharkland	23.996224	85.369318		Regular	Hazaribagh	DEPOSIT	192.98
Jharkland	24.264705	83.593786		Regular	Palamu	DEPOSIT	192.98
Jharkland	24.27557	87.253244		Regular	Santhal Pargana	DEPOSIT	192.98
Meghalaya	25.165093	92.379262	Barak Valley Cement Ltd./Meghalaya Minerals & Mines Ltd.	Regular	Meghalaya Minerals & Mines Ltd.	DEPOSIT	
Meghalaya	25.165622	92.369604	Star Cement/ Cement Manufacturing Co. Ltd	Regular	Khub	DEPOSIT	
Meghalaya	25.168644	91.690354	K. Singh Wann & Son	Regular		DEPOSIT	
Meghalaya	25.19043	92.402997	Jud Cements Ltd.	Regular		DEPOSIT	
Meghalaya	25.191218	92.358692	Adhunik Cement Ltd.	Regular		DEPOSIT	
Meghalaya	25.195138	91.629027	Lafarge Umiam Mining Pvt Ltd./Lum Mawshun Minerals Pvt Ltd.	Regular		DEPOSIT	2
Meghalaya	25.203959	92.378122	Barak Valley Cement Ltd./Meghalaya Minerals & Mines Ltd.	Regular	Meghalaya Cement Ltd.	DEPOSIT	
Meghalaya	25.259533	91.712003	Mawmluh Cherra Cement Ltd.	Regular	Mawmluh Cherra Mine	DEPOSIT	
Meghalaya	25.580794	91.886864	Lafarge Umiam Mining Pvt Ltd.	Regular	Corporate Office	OFFICE	
Odissa	18.6258333	82.91666667	Manoj Quarry	Regular	Quarry	DEPOSIT	
Odissa	20.268218	85.83338	IDC of Odissa Ltd.	Regular	Corporate Office	DEPOSIT	
Odissa	20.289103	85.842426	Kalinga Lime	Regular	Corporate Office	OFFICE	

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Odissa	20.292153	85.81093	Radharaman Minerals	Regular	Corporate Office	OFFICE	
Odissa	20.573871	82.931994	Patnaik Minerals Pvt. Ltd.	Regular	Sarmuhan Mine	DEPOSIT	
Odissa	21.372798	83.616713	ACC	Regular		PLANT	
Odissa	21.629179	85.581519	Patnaik Minerals Pvt. Ltd.	Regular	Registered Office	OFFICE	
Odissa	21.761562	85.445433	Essel Mining and Industies Ltd.	Regular		DEPOSIT	
Odissa	21.820813	84.951294	Saligram Khirwal	Regular	Bonrai Mine	DEPOSIT	
Odissa	22.108039	85.388263	Essel Mining and Industies Ltd.	Regular	Corporate Office	OFFICE	
Odissa	22.202738	84.487023	V.K. Lal	Regular	Tunmura-Jharbeda Mine	DEPOSIT	
Odissa	22.211889	84.430132	Om Ganesh Minerals	Regular	Telighana Mine	DEPOSIT	
Odissa	22.224753	84.818857	Kalinga Lime	Regular	Branch Office	OFFICE	
Odissa	22.227848	84.922303	R.A. Jalan	Regular	Dharura-Kukuda Mine	DEPOSIT	
Odissa	22.254017	84.509753	G.S. Sharma & Sons	Regular	Jharbeda Mine	DEPOSIT	
Odissa	22.25654	84.432685	Mideast Carbon Ltd.	Regular	Dahijira Mine	DEPOSIT	
Odissa	22.261883	84.579056	Patnaik Minerals Pvt. Ltd.	Regular	Alanda Mine	DEPOSIT	
Odissa	22.261883	84.579056	United Minerals	Regular	Alanda Mine	DEPOSIT	
Odissa	22.277925	84.724845	OCL India Ltd.	Regular	Lanjiberna Mine	DEPOSIT	
Odissa	22.277925	84.724845	R.V. Enterprisers	Regular	Lanjiberna-Katang Mine	DEPOSIT	
Odissa	22.279859	84.482495	Shiva Cement Ltd.	Regular	Khatkurbahal Mine	DEPOSIT	
Odissa	22.279859	84.482495	Sadasiva Tripathy	Regular	Khatkurbahal Mine	DEPOSIT	
Odissa	22.298586	84.900537	Patnaik Minerals Pvt. Ltd.	Regular	Kadalibahal Mine	DEPOSIT	
Odissa	22.401179	84.834018	Radharaman Minerals	Regular	Kusumpali-Baidnathpur Mine	DEPOSIT	
Odissa	22.407778	84.874485	Kalinga Lime	Regular	Purnapani-Bhojpur Mine	DEPOSIT	0.06

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Odissa	22.408962	84.71503	B.S.L.Co. Ltd	Regular		DEPOSIT	
Sikkim	27.133965	88.27493		Regular	Rangeet Valley Tectonic Window	DEPOSIT	
West Bengal	22.54943	88.357962	Patnaik Minerals Pvt. Ltd.	Regular	Corporate Office	OFFICE	
Chhattisgarh	21.259985	81.358991	ACC	Regular		DEPOSIT	

Table A12. Materials database – Myanmar – limestone (ERDC-CERL).

City	Latitude	Longitude	Company	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Lewe Naypyidaw	19.525829	96.428177	Max Cement	Regular	Limestone Quarry	DEPOSIT	
Thayet	19.2747222	95.15888889	The Republic of the Union of Myanmar, Ministry of Industries	Regular	Limestone Quarry for (31)	DEPOSIT	

Table A13. Materials database – Bangladesh – steel (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Barisal	22.690121	90.35888	A	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Barisal Office	OFFICE				
Chittagong	22.36	91.8	A	Bangladesh Steel and Engineering Corp.	Cyclical	Tube	Plant at Chittagong	PLANT	0.02		54.70	ESTIMATED

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Chittagong	22.331395	91.831244	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Chittagong Office	OFFICE				
Chittagong	22.870921	91.546463	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Chittagong Steel Plant	PLANT	0.15		75	PUBLISHED
Chittagong	22.380432	91.767833	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Chittagong Steel Plant	PLANT	0.15		75	PUBLISHED
Chittagong	23.449927	91.185665	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Chittagong Steel Plant	PLANT	0.15		410.28	ESTIMATED
Chittagong	22.39277778	91.82055556	S	KDS Group	Cyclical	Sheet	Head Office	OFFICE				
Chittagong	22.49944444	91.71583333	S	KDS Group	Cyclical	Sheet	Factory	PLANT				
Chittagong	22.32055	91.811585	S	KSRM Steel Plant Ltd.	Cyclical	Angle, Channel	Corporate Office	OFFICE				
Chittagong	23.459588	91.17455	S	KSRM Steel Plant Ltd.	Cyclical	Angle, Channel	Comilla Office	OFFICE				
Chittagong	22.503557	91.714607	S	KSRM Steel Plant Ltd.	Cyclical	Angle, Channel	KSRM Billets Industries Ltd.	PLANT	0.2		25	PUBLISHED
Chittagong	22.501614	91.716807	S	KSRM Steel Plant Ltd.	Cyclical	Angle, Channel	KSRM Re-Rolling Mills Ltd.	PLANT	0.2		25	PUBLISHED
Chittagong	22.4424	91.732	A		Cyclical	Recycled Steel	Chittagong Ship-Breaking Yard (Fauzdahart Beach)	DEPOSIT		200,000		
Chittagong	22.325769	91.813462	A	PHP Steel Industries	Cyclical	Sheet	Corporate Office	OFFICE				
Chittagong	22.51444444	91.71166667	S	PHP Steel Industries	Cyclical	Sheet	Production Plant	PLANT	0.25		683.8	ESTIMATED

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Chittagong	23.451509	91.147599	S	SAS Steel Mills Ltd.	Cyclical	Tube	Factory	PLANT				
Chittagong	22.327675	91.814144	S	Sheema Automatic Steel Re-rolling Mills Ltd.	Cyclical	Angle, Billet, Channel	Corporate Office	OFFICE				
Chittagong	22.41444444	91.75611111	S	Sheema Automatic Steel Re-rolling Mills Ltd.	Cyclical	Angle, Billet, Channel	Steel Mill	PLANT				
Chittagong	22.338731	91.844335	S	T.K. Group of Industries	Cyclical	Steel Shape	Corporate Office (Chittagong)	OFFICE				
Chittagong	22.5075	91.71361111	S	T.K. Group of Industries	Cyclical	Steel Shape	Karnaphully Steel Mill	PLANT	0.08		218.82	ESTIMATED
Dhaka	23.734126	90.409777	S	Bandar Steel Industries Ltd.	Cyclical	Billet	Corporate Office	OFFICE				
Dhaka	23.69	90.539355	S	Bandar Steel Industries Ltd.	Cyclical	Billet	Dhaka Steel Plant	PLANT				
Dhaka	23.90	90.402103	S	Bangladesh Steel and Engineering Corp.	Cyclical	Tube	National Tubes Ltd.	PLANT	0.039		49.89	ESTIMATED
Dhaka	23.824559	90.42961	S	Bashundhara Steel Complex Ltd.	Cyclical	Billet, Tube	Corporate Office	OFFICE				
Dhaka	23.89138889	90.03722222	S	Bashundhara Steel Complex Ltd.	Cyclical	Billet, Tube	Factory	PLANT				
Dhaka	23.736393	90.412547	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Dhaka Corporate Office	OFFICE				

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.856957	90.40178	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Uttara Office	OFFICE				
Dhaka	23.791323	90.36519	S	BSRM Steel Mills Ltd.	Cyclical	Flat Bar, Channel, I Beam, H Beam, Shaft	Dhaka Steel Plant	PLANT	0.15		410.28	ESTIMATED
Dhaka	23.67067	90.454831	S	Chakda Steel and Re-rolling Mills Pvt. Ltd.	Cyclical	Angle, Billet, Ingot, Square Bar, Z Bar	Factory	PLANT				
Dhaka	23.695933	90.495717	S	F.M.S. Steel Mills Ltd.	Cyclical	Tube	Steel Pipe Mill	PLANT				
Dhaka	23.738071	90.381116	S	Haque Steel Group	Cyclical	Billet, Various Steel Shapes	Corporate Office	OFFICE				
Dhaka	23.600147	90.614683	S	Haque Steel Group	Cyclical	Billet, Various Steel Shapes	Steel Mill	PLANT				
Dhaka	23.753898	90.391841	S	Hossains' Group	Cyclical	Angle, Chan-nel, Flat Bar	Head Office	OFFICE				
Dhaka	23.718842	90.483697	S	Hossains' Group	Cyclical	Angle, Chan-nel, Flat Bar	Ali & Shohag Steels & Re-Rolling Co. Ltd.	PLANT	0.005	400	13.68	ESTIMATED
Dhaka	23.721948	90.502059	S	Hossains' Group	Cyclical	Angle, Chan-nel, Flat Bar	Faisal Steel & Re-Rolling Co. Ltd.	PLANT	0.01	227	27.35	ESTIMATED
Dhaka	23.638009	90.482862	S	Hossains' Group	Cyclical	Angle, Chan-nel, Flat Bar	Jamuna Steel & Re-Rolling Co. Ltd.	PLANT	0.016	325	43.76	ESTIMATED
Dhaka	23.771742	90.377368	S	Hossains' Group	Cyclical	Angle, Chan-nel, Flat Bar	Tejgaon Re-Rolling Co. Ltd.	PLANT	0.015	300	41.03	ESTIMATED
Dhaka	23.711771	90.349361	S	Hossains' Group	Cyclical	Angle, Chan-nel, Flat Bar	Steel Mill	PLANT				
Dhaka	23.795688	90.402004	S	KDS Group	Cyclical	Steel Shape	Dhaka Office	OFFICE				
Dhaka	23.746518	90.392458	S	KSRM Steel Plant Ltd.	Cyclical	Steel Shape	Dhaka Office - Banglamotor	OFFICE				

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.794647	90.414716	S	KSRM Steel Plant Ltd.	Cyclical	Steel Shape	Dhaka Office - Gulshan	OFFICE				
Dhaka	23.770488	90.406399	S	McDonald Steel Ltd.	Cyclical	Built-up Section, Plate	Corporate Office	OFFICE				
Dhaka	24.088965	90.373771	A	McDonald Steel Ltd.	Cyclical	Built-up Section, Plate	Steel Mill	PLANT	0.15		410.28	ESTIMATED
Dhaka	23.744726	90.447247	S	Rahim Steel Mills Co. (Pvt.) Ltd.	Cyclical	Billet, Plate	Corporate Office	OFFICE				
Dhaka	23.70065	90.532507	S	Rahim Steel Mills Co. (Pvt.) Ltd.	Cyclical	Billet, Plate	Dhaka Steel Plant	PLANT	0.016		2.5	PUBLISHED
Dhaka	23.678542	90.441615	S	Rahim Steel Mills Co. (Pvt.) Ltd./Diamond Steel Produces Co. (Pvt.) Ltd.	Cyclical	Billet, Plate	Dhaka Steel Plant	PLANT	0.016		2.5	PUBLISHED
Dhaka	23.70065	90.532507	S	Rahim Steel Mills Co. (Pvt.) Ltd./Sonargaon Steels Ltd.	Cyclical	Billet, Plate	Dhaka Steel Plant	PLANT	0.016		2.5	PUBLISHED
Dhaka	23.794377	90.424245	S	Rani Re-Rolling Mills Ltd.	Cyclical	Angle, Billet	Corporate Office	OFFICE				
Dhaka	23.674811	90.448272	S	Rani Re-Rolling Mills Ltd.	Cyclical	Angle, Billet	Steel Mill	PLANT		500		
Dhaka	23.746876	90.392832	S	Sarker Steel Ltd.	Cyclical	Joist, Deck, Wall Panel	Corporate Office	OFFICE				
Dhaka	23.919413	90.112158	S	Sarker Steel Ltd.	Cyclical	Joist, Deck, Wall Panel	Factory	PLANT				
Dhaka	23.799327	90.407333	S	SAS Steel Mills Ltd.	Cyclical	Steel Shape	Corporate Office	OFFICE				

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.719582	90.419016	S	Sheema Automatic Steel Re-rolling Mills Ltd.	Cyclical	Steel Shape	Dhaka Office	OFFICE				
Dhaka	23.751189	90.393294	S	T.K. Group of Industries	Cyclical	Steel Shape	Corporate Office (Dhaka)	OFFICE				
Dhaka	23.743421	90.386679	S	Vikrampur Steel Ltd.	Cyclical	Angle, Chan-nel	Head Office	OFFICE				
Dhaka	23.813115	90.537975	A	Vikrampur Steel Ltd.	Cyclical	Angle, Chan-nel	Factory	PLANT				
Khulna	22.915798	89.503482	A	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Khulna Office	OFFICE				
Khulna	23.449945	91.185765	S	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Comilla Office	OFFICE				
Khulna	22.806506	89.569303	S	KSRM Steel Plant Ltd.	Cyclical	Steel Shape	Khulna Office	OFFICE				
Rajshahi	24.839288	89.347628	S	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Bogra Office	OFFICE				
Rajshahi	24.363326	88.604359	A	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Rajshahi Office	OFFICE				
Rajshahi	25.756035	89.230816	S	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Rangpur Office	OFFICE				
Rajshahi	24.843886	89.36941	S	KSRM Steel Plant Ltd.	Cyclical	Steel Shape	Bogra Office	OFFICE				
Sylhet	24.885862	91.88149	S	BSRM Steel Mills Ltd.	Cyclical	Steel Shape	Sylhet Office	OFFICE				
Sylhet	24.889181	91.887322	S	KSRM Steel Plant Ltd.	Cyclical	Steel Shape	Sylhet Office	OFFICE				

Table A14. Materials Database – India – Steel (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Assam	26.182547	91.74129	S	JSW Steel	Cyclical	Steel Shape	Corporate Office	OFFICE				
Assam	26.160922	91.773636	S	Satyam Steel Pvt. Ltd.	Cyclical	Steel Shape	Corporate Office	OFFICE				
Assam	25.901233	93.696907	S	Steel Authority of India Ltd.	Cyclical	Plate, Sheet	Corporate Office	OFFICE				
Bihar	23.67	86.11	S	Steel Authority of India Ltd.	Cyclical	Plate, Sheet	Bokaro Steel Plant	PLANT	4.6		5884.32	ESTIMATED
Chhattisgarh	21.28388889	81.60638889	S	Amrit	Cyclical	Angle, Round Bar, Square Bar	Steel Rolling Mill	PLANT				
Chhattisgarh	21.369973	81.684679	S	Godawari Power and Ispat Ltd.	Cyclical	Billet	Steel Mill	PLANT	0.3		383.76	ESTIMATED
Chhattisgarh	21.93083333	83.34277778	S	Jindal Steel and Power Ltd.	Cyclical	Plate	Plate Mill	PLANT	1		894	PUBLISHED
Chhattisgarh	22.021991	83.380209	S	Nalwa Steel and Power Ltd.	Cyclical	Billet	Nalwa Steel and Power Ltd.	PLANT				
Chhattisgarh	21.365716	81.681588	S	Sarda Energy and Minerals Ltd.	Cyclical	Billet	Works	PLANT				
Chhattisgarh	21.365716	81.681588	S	Sarda Energy and Minerals Ltd.	Cyclical	Billet	Head Office	OFFICE				
Chhattisgarh	21.908255	83.390436	A	Sarda Energy and Minerals Ltd.	Cyclical	Billet	Raigarh Office	OFFICE				
Chhattisgarh	21.305459	81.615691	A	Shri Bajrang Alloys Ltd.	Cyclical	Angle, Beam, Channel, Flat, H Beam, Round Bar	Shri Bajrang Alloys Ltd.	PLANT	0.05	150	63.96	ESTIMATED
Chhattisgarh	21.277809	81.601488	S	SKS Ispat Pvt. Ltd.	Cyclical	Angle, Beam, Billet, Bloom, Channel, H Beam	Corporate Office	OFFICE				

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Chhattisgarh	21.39111111	81.64666667	S	SKS Ispat Pvt. Ltd.	Cyclical	Angle, Beam, Billet, Bloom, Channel, H Beam	Steel Plant	PLANT	0.363		85	PUBLISHED
Chhattisgarh	21.19	81.39	S	Steel Authority of India Ltd.	Cyclical	Beam, Billet, Bloom, Channel, Plate	Bhilai steel plant	PLANT	3.153		4033.32	ESTIMATED
Chhattisgarh	19.07	81.99	A	Tata Iron and Steel Co. Ltd.	Cyclical	Plate, Sheet, Tube	Tata steel plant at Jagdalpur	PLANT	3		3837.60	ESTIMATED
Chhattisgarh	21.257447	81.561251	A	Tirupati Steel	Cyclical	Steel Shape	Head Office	OFFICE				
Chhattisgarh	21.189587	81.199811	S	Topworth Group	Cyclical	Billet, Bloom, Tube, Various Steel Shapes	Crest Steel and Power Ltd.	PLANT	1		1279.20	ESTIMATED
Chhattisgarh	21.188091	81.211992	S	Topworth Group	Cyclical	Billet, Bloom, Tube, Various Steel Shapes	Topworth Steel and Power Pvt. Ltd.	PLANT	1		1279.20	ESTIMATED
Chhattisgarh	21.232994	81.658278	S	Vandana Global Ltd.	Cyclical	Beam, Angle, Channel, H Beam, Flat, Joist, Round	Corporate Office	OFFICE				
Chhattisgarh	21.251901	81.625084	A	Vandana Global Ltd.	Cyclical	Beam, Angle, Channel, H Beam, Flat, Joist, Round	Steel Mill	PLANT	0.225		287.82	ESTIMATED
Jharkhand	23.348991	85.304465	S	JSW Steel	Cyclical	Steel Shape	Corporate Office	OFFICE				
Jharkhand	22.79	86.2	S	Tata Iron and Steel Co. Ltd.	Cyclical	Plate, Sheet, Tube	Jamshedpur Steel Plant	PLANT	9.7		12408.24	ESTIMATED
Jharkhand	23.748838	86.151416	A	Zoom Vallabh Steels Ltd.	Cyclical	Ingot, Sheet, Tube	Steel Mill	PLANT	0.2	3000	255.84	ESTIMATED
Meghalaya	26.073047	91.872281	S	Satyam Steel Pvt. Ltd.	Cyclical	Billet	Steel Mill	PLANT	0.17		217.46	ESTIMATED
Orissa	20.51833333	85.73027778	S	Aarti Steels Ltd.	Cyclical	Billet, Flat, Round Bar, Square Bar	Works	PLANT			90	PUBLISHED

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Require-ments (MW)	Electric Require-ment Source
Orissa	21.843123	83.98113	S	Action Ispat and Power Pvt. Ltd.	Cyclical	Steel Shape	Steel Mill	PLANT	0.25		319.80	ESTIMATED
Orissa	22.30826	84.764113	S	Adhunik Group	Cyclical	Billet, Bloom, Channel, Round Bar, Various Steel Shapes	Adhunik Metaliks Ltd.	PLANT	0.45		575.64	ESTIMATED
Orissa	20.284114	85.815332	S	Bhushan Group	Cyclical	Steel Shape	Bhushan Steel and Strips Ltd.	OFFICE				
Orissa	21.761712	84.020053	S	Bhushan Steel and Power Ltd.	Cyclical	Billet	Steel Mill	PLANT	2.3		376	PUBLISHED
Orissa	22.082109	84.857954	A	Jai Balaji Group	Cyclical	Billet	Jai Balaji Jyoti Steels Ltd.	PLANT	0.1142		146.08	ESTIMATED
Orissa	21.91277778	84.02944444	S	Jain Steel and Power Ltd.	Cyclical	Steel Shape	Steel Melting and Power Plant	PLANT	0.08		8	PUBLISHED
Orissa	20.88166667	84.98944444	S	Jindal Steel and Power Ltd.	Cyclical	Plate	Plate Mill	PLANT	1.2		20	PUBLISHED
Orissa	20.96833333	86.04916667	A	Mesco Steel	Cyclical	Plate	Steel Plant	PLANT				
Orissa	21.8075	85.56805556	S		Cyclical	Billet	Steel Mill	PLANT				
Orissa	22.188017	84.580082	A	OCL Iron and Steel Ltd.	Cyclical	Billet	Registered Office	OFFICE				
Orissa	22.213088	84.551887	S	OCL Iron and Steel Ltd.	Cyclical	Billet	Works	PLANT			18	PUBLISHED
Orissa	19.24805556	84.77444444	S	Pentagon Steels India Pvt. Ltd.	Cyclical	Cladding Sheet, Roof-ing Sheet	Steel Plant	PLANT	0.02		25.58	ESTIMATED
Orissa	22.112995	85.374732	A	Shyam Steel Industries Ltd.	Cyclical	Angle, Beam, Channel, Flat, Round	Steel Mill	PLANT	0.280		358.18	ESTIMATED
Orissa	21.683792	85.4358	A	Sree Metaliks Ltd.	Cyclical	Billet	Head Of-fice	OFFICE				

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Orissa	21.683792	85.4358	S	Sree Metaliks Ltd.	Cyclical	Billet	Steel Mill	PLANT	0.29		28	PUBLISHED
Orissa	22.21	84.86	S	Steel Authority of India Ltd.	Cyclical	Plate, Sheet, Tube	Rourkela steel plant	PLANT	12.6		16117.92	ESTIMATED
Orissa	21.00	86.02	S	Tata Iron and Steel Co. Ltd.	Cyclical	Plate, Sheet, Tube	Tata steel plant at Duburi	PLANT	3		3837.60	ESTIMATED
Orissa	20.943447	86.061403	S	Visa Steel	Cyclical	Angle, Billet, Bloom, Flat	Steel Mill	PLANT	0.5		75	PUBLISHED
West Bengal	22.539922	88.355051	S	Beekay Steel and Power Ltd.	Cyclical	Steel Shape	Corporate Office	OFFICE				
West Bengal	22.551723	88.352488	S	Bhushan Group	Cyclical	Steel Shape	Corporate Office	OFFICE				
West Bengal	22.729469	88.314832	S	Bhushan Steel and Power Ltd.	Cyclical	Sheet, Tube	Steel Mill	PLANT				
West Bengal	22.570969	88.352953	S	Jai Balaji Group	Cyclical	Billet, Tube	Registered Office	OFFICE				
West Bengal	23.520857	87.309785	A	Jai Balaji Group	Cyclical	Billet, Tube	Jai Balaji Industries Ltd.	PLANT	1.14623		1466.26	ESTIMATED
West Bengal	22.546175	88.353214	S	JSW Steel	Cyclical	Steel Shape	Corporate Office	OFFICE				
West Bengal	22.583024	88.44938	S	JSW Steel	Cyclical	Steel Shape	Corporate Office	OFFICE				
West Bengal	22.568321	88.350967	S	Mortex Group	Cyclical	Steel Shape	Corporate Office	OFFICE				
West Bengal	22.93666667	88.38611111	S		Cyclical	Steel Shape	Steel Plant	PLANT				
West Bengal	22.573745	88.431548	S	Shyam Steel Industries Ltd.	Cyclical	Angle, Channel, Beam, Round Bar, Square Bar, Flat, Billet	Corporate Office	OFFICE		14,000		
West Bengal	23.50855	87.282358	S	Shyam Steel Industries Ltd.	Cyclical	Angle, Channel, Beam, Round Bar, Square Bar, Flat, Billet	Steel Mill	PLANT	1.1		1000	PUBLISHED

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
West Bengal	22.541317	88.356191	S	SPS Group	Cyclical	Angle, Beam, Channel, Flat, Round Bar	Corporate Office	OFFICE				
West Bengal	23.513214	87.331602	S	SPS Group	Cyclical	Angle, Beam, Channel, Flat, Round Bar	SPS Steels Re-rolling Mill	PLANT	0.6		767.52	ESTIMATED
West Bengal	22.545075	88.35502	S	Sree Metaliks Ltd.	Cyclical	Angle, Channel, Beam, Round Bar, Square Bar, Flat, Billet	Registered Office	OFFICE				
West Bengal	23.68	86.94	S	Steel Authority of India Ltd.	Cyclical	Angle, Beam, Bulb Bar, Channel, Z Bar	Burnpur Steel Plant	PLANT	1.5		1918.80	ESTIMATED
West Bengal	23.664624	86.916084	S	Steel Authority of India Ltd.	Cyclical	Angle, Beam, Bulb Bar, Channel, Z Bar	IISCO Steel Plant	PLANT	2.5		3198.00	ESTIMATED
West Bengal	23.52388889	87.13222222	S	Tirupati Steel	Cyclical	Steel Shape	Steel Mill	PLANT				
West Bengal	22.545113	88.353565	S	Visa Steel	Cyclical	Steel Shape	Corporate Office	OFFICE				

Table A15. Materials Database – Bangladesh – steel (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Mandalay	21.98611111	96.40666667	S	Republic of the Union of Myanmar, Ministry of Industry	Cyclical	Billet, Sheet, Slab, Tube	No. (1) Steel Mill (Myingyan)	PLANT	0.988		1263.85	ESTIMATED

City	Latitude	Longitude	Precision	Company	Industry Type	Product	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Electric Requirements (MW)	Electric Requirement Source
Yangon	16.81	96.22	A	Myanmar POSCO Steel Co. Ltd.	Cyclical	Angle, Channel, Beam, Round Bar, Square Bar, Flat, Billet	POSCO Steel Plant	PLANT	0.03		38.38	ESTIMATED

Table A16. Materials database – Bangladesh – steel rebar (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Quality	Electric Requirements (MW)	Electric Requirement Source
Barisal	22.690121	90.35888	A	BSRM Steel Mills Ltd.	Cyclical	Barisal Office	OFFICE			400W-500W		
Chittagong	22.348398	91.796378	S	AKS	Cyclical	Corporate Office	OFFICE		163	500W		
Chittagong	22.47138889	91.73416667	S	AKS	Cyclical	AKS Steel Melting Ltd.	PLANT	1.2	163	500W	1747.2	ESTIMATED
Chittagong	22.44416667	91.73972222	S	AKS	Cyclical	Steel Mill	PLANT	1.2	163	500W	1535.04	ESTIMATED
Chittagong	22.388363	91.807406	S	Asif Steel Mill	Cyclical	Steel Mill	PLANT					
Chittagong	22.37	91.81484	S	Baizid Steel Industries Ltd.	Cyclical	Factory	PLANT			500W	27	PUBLISHED
Chittagong	22.36	91.821712	S	Baizid Steel Industries Ltd.	Cyclical	Corporate Office	OFFICE					
Chittagong	22.331395	91.831244	S	BSRM Steel Mills Ltd.	Cyclical	Chittagong Office	OFFICE			400W-500W		
Chittagong	22.870921	91.546463	S	BSRM Steel Mills Ltd.	Cyclical	Chittagong Steel Plant	PLANT	0.15		400W-500W	75	PUBLISHED
Chittagong	22.380432	91.767833	S	BSRM Steel Mills Ltd.	Cyclical	Chittagong Steel Plant	PLANT	0.15		400W-500W	75	PUBLISHED
Chittagong	23.449927	91.185665	S	BSRM Steel Mills Ltd.	Cyclical	Chittagong Steel Plant	PLANT	0.15		400W-500W	410.28	ESTIMATED

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Quality	Electric Requirements (MW)	Electric Requirement Source
Chittagong	22.425349	91.738518	S	Ferdous Steel Corporation	Cyclical	Steel Mill	PLANT					
Chittagong	22.4609	91.729652	S	Golden Steel Ltd.	Cyclical	Steel Mill	PLANT					
Chittagong	22.36861111	91.81555556	S	Islam Steel Mills Ltd.	Cyclical	Steel Mill	PLANT			500W		
Chittagong	22.378972	91.769421	S	Javed Steel Mills Ltd.	Cyclical	Steel Mill	PLANT					
Chittagong	22.354041	91.790988	S	Kazi Steel Industries	Cyclical	Steel Mill	PLANT					
Chittagong	22.32055	91.811585	S	KSRM Steel Plant Ltd.	Cyclical	Corporate Office	OFFICE			400W - 500W		
Chittagong	22.503557	91.714607	S	KSRM Steel Plant Ltd.	Cyclical	KSRM Billets Industries Ltd.	PLANT	0.2		400W - 500W	25	PUBLISHED
Chittagong	22.501614	91.716807	S	KSRM Steel Plant Ltd.	Cyclical	KSRM Re-Rolling Mills Ltd.	PLANT	0.2		400W - 500W	25	PUBLISHED
Chittagong	22.482921	91.722183	S	Madina Oxygen and Steel Ltd.	Cyclical	Steel Mill	PLANT					
Chittagong	22.415	91.75305556	S	Mirza Steel Re-Rolling Mills	Cyclical	Steel Mill	PLANT					
Chittagong	22.350607	91.825318	S	Mirzaboo Steels Ltd.	Cyclical	Corporate Office	OFFICE					
Chittagong	22.39304	91.817973	S	Mirzaboo Steels Ltd.	Cyclical	Steel Mill	PLANT					
Chittagong	22.4424	91.732	A		Cyclical	Chittagong Ship-Breaking Yard (Fauzdahart Beach)	DEPOSIT		200000			
Chittagong	22.325769	91.813462	A	PHP Steel Industries	Cyclical	Corporate Office	OFFICE			500W		
Chittagong	22.51444444	91.71166667	S	PHP Steel Industries	Cyclical	Production Plant	PLANT	0.25		500W	683.8	ESTIMATED
Chittagong	22.340416	91.814707	S	Ratanpur Steel Re-Rolling Mills Ltd.	Cyclical	Head Office	OFFICE			300W-400W-500W		

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Quality	Electric Requirements (MW)	Electric Requirement Source
Chittagong	22.391054	91.811175	S	Ratanpur Steel Re-Rolling Mills Ltd.	Cyclical	Factory	PLANT			300W-400W-500W		
Chittagong	22.45944444	91.73166667	S	S. L. Steel & Re-Rolling	Cyclical	Steel Mill	PLANT					
Chittagong	22.374036	91.813118	S	Saleh Steel Re-Rolling Mill	Cyclical	Steel Mill	PLANT					
Chittagong	23.451509	91.147599	S	SAS Steel Mills Ltd.	Cyclical	Factory	PLANT			500W		
Chittagong	22.327675	91.814144	S	Sheema Automatic Steel Re-rolling Mills Ltd.	Cyclical	Corporate Office	OFFICE			300W-400W-500W		
Chittagong	22.41444444	91.75611111	S	Sheema Automatic Steel Re-rolling Mills Ltd.	Cyclical	Steel Mill	PLANT			300W-400W-500W		
Chittagong	22.372451	91.774934	S	Sitalpur Auto Steel Mills Ltd.	Cyclical	Corporate Office	OFFICE			500W		
Chittagong	22.372451	91.774934	A	Sitalpur Auto Steel Mills Ltd.	Cyclical	Steel Mill	PLANT	0.15		500W	410.28	ESTIMATED
Chittagong	22.346342	91.838234	S	United Steel Industries	Cyclical	Steel Mill	PLANT					
Dhaka	23.797373	90.365145	A	AKS	Cyclical	Corporate Office	OFFICE		163	500W		
Dhaka	23.734029	90.409874	S	Ambient Steel (BD) Ltd.	Cyclical	Corporate Office	OFFICE			300W-400W-500W		
Dhaka	23.816395	90.538528	A	Ambient Steel (BD) Ltd.	Cyclical	Steel Mill	PLANT			300W-400W-500W		
Dhaka	23.75	90.391732	S	Baizid Steel Industries Ltd.	Cyclical	Dhaka Office	OFFICE					

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.734126	90.409777	S	Bandar Steel Industries Ltd.	Cyclical	Corporate Office	OFFICE			300W-400W-500W		
Dhaka	23.69	90.539355	S	Bandar Steel Industries Ltd.	Cyclical	Dhaka Steel Plant	PLANT			300W-400W-500W		
Dhaka	23.687146	90.434484	S	Based & Sons Steel Re-Rolling Mills	Cyclical	Steel Mill	PLANT					
Dhaka	23.824559	90.42961	S	Bashundhara Steel Complex Ltd.	Cyclical	Corporate Office	OFFICE			300W-400W		
Dhaka	23.89138889	90.03722222	S	Bashundhara Steel Complex Ltd.	Cyclical	Factory	PLANT			300W-400W		
Dhaka	23.69	90.45861111	S	Bipasha Steel Fabrication and Hardware	Cyclical	Steel Mill	PLANT					
Dhaka	23.736393	90.412547	S	BSRM Steel Mills Ltd.	Cyclical	Dhaka Corporate Office	OFFICE			400W-500W		
Dhaka	23.856957	90.40178	S	BSRM Steel Mills Ltd.	Cyclical	Uttara Office	OFFICE			400W-500W		
Dhaka	23.791323	90.36519	S	BSRM Steel Mills Ltd.	Cyclical	Dhaka Steel Plant	PLANT	0.15		400W-500W	410.28	ESTIMATED
Dhaka	23.67067	90.454831	S	Chakda Steel and Re-rolling Mills Pvt. Ltd.	Cyclical	Factory	PLANT			300W-400W-500W		
Dhaka	23.632934	90.477218	S	Chittagong Steel Works Ltd.	Cyclical	Steel Mill	PLANT					
Dhaka	23.810912	90.413275	A	Chittagong Steel Works Ltd.	Cyclical	Corporate Office	OFFICE					
Dhaka	23.695933	90.495717	S	F.M.S. Steel Mills Ltd.	Cyclical	Steel Pipe Mill	PLANT					

City	Latitude	Longitude	Preci-sion	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.79694444	90.26305556	S	Fajlul Karim Steel and Re-rolling Mills Ltd	Cyclical	Dhaka Steel Plant	PLANT					
Dhaka	23.738071	90.381116	S	Haque Steel Group	Cyclical	Corporate Office	OFFICE					
Dhaka	23.600147	90.614683	S	Haque Steel Group	Cyclical	Steel Mill	PLANT					
Dhaka	23.753898	90.391841	S	Hossains' Group	Cyclical	Head Office	OFFICE					
Dhaka	23.718842	90.483697	S	Hossains' Group	Cyclical	Ali & Shohag Steels & Re-Rolling Co. Ltd.	PLANT	0.005	400		13.68	ESTIMATED
Dhaka	23.721948	90.502059	S	Hossains' Group	Cyclical	Faisal Steel & Re-Rolling Co. Ltd.	PLANT	0.01	227		27.35	ESTIMATED
Dhaka	23.638009	90.482862	S	Hossains' Group	Cyclical	Jamuna Steel & Re-Rolling Co. Ltd.	PLANT	0.016	325		43.76	ESTIMATED
Dhaka	23.771742	90.377368	S	Hossains' Group	Cyclical	Tejgaon Re-Rolling Co. Ltd.	PLANT	0.015	300		41.03	ESTIMATED
Dhaka	23.711771	90.349361	S	Hossains' Group	Cyclical	Steel Mill	PLANT					
Dhaka	23.876106	90.384246	A	Jalalabad Steel Building Ltd.	Cyclical	Corporate Of-fice	OFFICE					
Dhaka	23.79777778	90.2625	S	Jalalabad Steel Building Ltd.	Cyclical	Dhaka Steel Plant	PLANT					
Dhaka	23.79361111	90.25611111	S	Jalalabad Steel Building Ltd.	Cyclical	Dhaka Steel Plant	PLANT					
Dhaka	23.746518	90.392458	S	KSRM Steel Plant Ltd.	Cyclical	Dhaka Office - Banglamotor	OFFICE			400W - 500W		
Dhaka	23.794647	90.414716	S	KSRM Steel Plant Ltd.	Cyclical	Dhaka Office - Gulshan	OFFICE			400W - 500W		

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employees	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.776946	90.414094	S	Magnum Steel Industries Ltd.	Cyclical	Corporate Office	OFFICE			500W		
Dhaka	23.554084	90.659124	S	Magnum Steel Industries Ltd.	Cyclical	Steel Mill	PLANT			500W		
Dhaka	23.707525	90.503658	S	Mohammadi Steel Works Ltd.	Cyclical	Steel Mill	PLANT					
Dhaka	23.734026	90.40987	S	Mohammadi Steel Works Ltd.	Cyclical	Corporate Office	OFFICE					
Dhaka	23.797228	90.263372	S		Cyclical	Steel Re-Rolling Factory	PLANT					
Dhaka	23.678471	90.443711	S	Pioneer Steel Re-Rolling Mills Ltd.	Cyclical	Steel Mill	PLANT					
Dhaka	23.751672	90.54346	S	Premier Steel and Re-Rolling Mills Ltd.	Cyclical	Steel Mill	PLANT					
Dhaka	23.771422	90.401887	S	Purbachal Steel Mills Ltd.	Cyclical	Corporate Office	OFFICE			400W-500W		
Dhaka	23.993879	90.406488	S	Purbachal Steel Mills Ltd.	Cyclical	Factory	PLANT			400W-500W		
Dhaka	23.744726	90.447247	S	Rahim Steel Mills Co. (Pvt.) Ltd.	Cyclical	Corporate Office	OFFICE					
Dhaka	23.70065	90.532507	S	Rahim Steel Mills Co. (Pvt.) Ltd.	Cyclical	Dhaka Steel Plant	PLANT	0.016			2.5	PUBLISHED
Dhaka	23.678542	90.441615	S	Rahim Steel Mills Co. (Pvt.) Ltd./Diamond Steel Produces Co. (Pvt.) Ltd.	Cyclical	Dhaka Steel Plant	PLANT	0.016			2.5	PUBLISHED

City	Latitude	Longitude	Preci-sion	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.70065	90.532507	S	Rahim Steel Mills Co. (Pvt.) Ltd./So-nargaon Steels Ltd.	Cyclical	Dhaka Steel Plant	PLANT	0.016			2.5	PUBLISHED
Dhaka	23.794377	90.424245	S	Rani Re-Roll-ing Mills Ltd.	Cyclical	Corporate Of-fice	OFFICE			300W-400W-500W-550W		
Dhaka	23.674811	90.448272	S	Rani Re-Roll-ing Mills Ltd.	Cyclical	Steel Mill	PLANT		500	300W-400W-500W-550W		
Dhaka	23.788542	90.416085	S	Ratanpur Steel Re-Roll-ing Mills Ltd.	Cyclical	Corporate Of-fice	OFFICE			300W-400W-500W		
Dhaka	23.731602	90.418162	S	Ratanpur Steel Re-Roll-ing Mills Ltd.	Cyclical	Share Dept.	OFFICE			300W-400W-500W		
Dhaka	23.799327	90.407333	S	SAS Steel Mills Ltd.	Cyclical	Corporate Office	OFFICE					
Dhaka	23.780752	90.402819	S	SCRM	Cyclical	Corporate Office	OFFICE			400W-500W		
Dhaka	23.880227	90.402474	A	SCRM	Cyclical	Factory	PLANT			400W-500W		
Dhaka	23.717644	90.466548	S	Shahriar Steel Re-Roll-ing Mills Ltd.	Cyclical	Factory and Head Office	PLANT			300W-400W-500W		
Dhaka	23.68527778	90.43638889	S	Shampur Based Steel Mills Ltd.	Cyclical	Dhaka Steel Plant	PLANT					
Dhaka	23.96666667	90.40194444	S	Shampur Based Steel Mills Ltd.	Cyclical	Dhaka Steel Plant	PLANT					
Dhaka	23.719582	90.419016	S	Sheema Au-tomatic Steel Re-rolling Mills Ltd.	Cyclical	Dhaka Office	OFFICE			300W-400W-500W		

City	Latitude	Longitude	Preci-sion	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Requirements (MW)	Electric Requirement Source
Dhaka	23.752446	90.379773	S	SS Steel Pvt. Ltd.	Cyclical	Corporate Office	OFFICE			500W		
Dhaka	23.89565	90.394435	S	SS Steel Pvt. Ltd.	Cyclical	Factory	PLANT			500W		
Dhaka	23.71805556	90.47583333	S	Sufia Re-roll-ing Mills	Cyclical	Steel Mill	PLANT					
Dhaka	23.743421	90.386679	S	Vikrampur Steel Ltd.	Cyclical	Head Office	OFFICE			300W-500W		
Dhaka	23.813115	90.537975	A	Vikrampur Steel Ltd.	Cyclical	Factory	PLANT			300W-500W		
Khulna	22.915798	89.503482	A	BSRM Steel Mills Ltd.	Cyclical	Khulna Office	OFFICE			400W-500W		
Khulna	23.449945	91.185765	S	BSRM Steel Mills Ltd.	Cyclical	Comilla Office	OFFICE			400W-500W		
Khulna	22.783093	89.580982	S	Koreshi Steel Industry Ltd.	Cyclical	Industrial Area	PLANT					
Mongla	23.459588	91.17455	S	KSRM Steel Plant Ltd.	Cyclical	Comilla Office	OFFICE			400W - 500W		
Mongla	22.806506	89.569303	S	KSRM Steel Plant Ltd.	Cyclical	Khulna Office	OFFICE			400W - 500W		
Rajshahi	24.839288	89.347628	S	BSRM Steel Mills Ltd.	Cyclical	Bogra Office	OFFICE			400W-500W		
Rajshahi	24.363326	88.604359	A	BSRM Steel Mills Ltd.	Cyclical	Rajshahi Of-fice	OFFICE			400W-500W		
Rajshahi	25.756035	89.230816	S	BSRM Steel Mills Ltd.	Cyclical	Rangpur Of-fice	OFFICE			400W-500W		
Rajshahi	24.843886	89.36941	S	KSRM Steel Plant Ltd.	Cyclical	Bogra Office	OFFICE			400W - 500W		
Sylhet	24.885862	91.88149	S	BSRM Steel Mills Ltd.	Cyclical	Sylhet Office	OFFICE			400W-500W		
Sylhet	24.889181	91.887322	S	KSRM Steel Plant Ltd.	Cyclical	Sylhet Office	OFFICE			400W - 500W		

Table A17. Materials database – India – steel rebar (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Require-ments (MW)	Electric Requirement Source
Assam	26.182547	91.74129	S	JSW Steel	Cyclical	Corporate Office	OFFICE					
Assam	25.901233	93.696907	S	Steel Authority of India Ltd.	Cyclical	Corporate Office	OFFICE					
Chhattisgarh	22.014354	83.402977	A	Anjani Steel Ltd.	Cyclical	Rolling Mill	PLANT	0.125		500	12	PUBLISHED
Chhattisgarh	21.293755	81.615774	S	Goel Group	Cyclical	Shri Bajrang Power and Ispat Ltd.	PLANT	0.128			26	PUBLISHED
Chhattisgarh	21.251376	81.62969	S	Monnet Group	Cyclical	Registered Office	OFFICE					
Chhattisgarh	21.243864	81.770947	S	Monnet Group	Cyclical	Monnet Ispat and Power Ltd.	PLANT	0.75			959	ESTIMATED
Chhattisgarh	21.226538	81.773203	S	Monnet Group	Cyclical	Monnet Ispat and Power Ltd.	PLANT	0.75			959	ESTIMATED
Chhattisgarh	22.021991	83.380209	S	Nalwa Steel and Power Ltd.	Cyclical	Nalwa Steel and Power Ltd.	PLANT					
Chhattisgarh	21.262881	81.614732	A	Prakash Industries Ltd.	Cyclical	Rolled Prod-ucts Divi-sion	PLANT	0.45			576	ESTIMATED
Chhattisgarh	21.262881	81.614732	S	Prakash Indus-tries Ltd.	Cyclical	Corporate Office	OFFICE					
Chhattisgarh	22.06916667	82.135833 33	S	Rishi Iron and Steel	Cyclical	Steel Mill	PLANT					
Chhattisgarh	21.365716	81.681588	S	Sarda Energy and Minerals Ltd.	Cyclical	Works	PLANT					
Chhattisgarh	21.365716	81.681588	S	Sarda Energy and Minerals Ltd.	Cyclical	Head Office	OFFICE					
Chhattisgarh	21.908255	83.390436	A	Sarda Energy and Minerals Ltd.	Cyclical	Raigarh Of-fice	OFFICE					

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Require-ments (MW)	Electric Requirement Source
Chhattisgarh	21.277809	81.601488	S	SKS Ispat Pvt. Ltd.	Cyclical	Corporate Office	OFFICE					
Chhattisgarh	21.39111111	81.64666667	S	SKS Ispat Pvt. Ltd.	Cyclical	Steel Plant	PLANT	0.165			85	PUBLISHED
Chhattisgarh	21.19	81.39	S	Steel Authority of India Ltd.	Cyclical	Bhilai Steel Plant	PLANT	3.153			4033	ESTIMATED
Chhattisgarh	19.07	81.99	A	Tata Iron and Steel Co. Ltd.	Cyclical	Tata Steel Plant at Jagdalpur	PLANT	3			3838	ESTIMATED
Chhattisgarh	21.257447	81.561251	A	Tirupati Steel	Cyclical	Head Office	OFFICE					
Chhattisgarh	21.189587	81.199811	S	Topworth Group	Cyclical	Crest Steel and Power Ltd.	PLANT	1			1279	ESTIMATED
Chhattisgarh	21.188091	81.211992	S	Topworth Group	Cyclical	Topworth Steel and Power Pvt. Ltd.	PLANT	1			1279	ESTIMATED
Chhattisgarh	21.232994	81.658278	S	Vandana Global Ltd.	Cyclical	Corporate Office	OFFICE					
Chhattisgarh	21.251901	81.625084	A	Vandana Global Ltd.	Cyclical	Steel Mill	PLANT	0.1			128	ESTIMATED
Jharkhand	23.348991	85.304465	S	JSW Steel	Cyclical	Corporate Office	OFFICE					
Jharkhand	22.79	86.2	S	Tata Iron and Steel Co. Ltd.	Cyclical	Jamshedpur steel plant	PLANT	9.7			12408	ESTIMATED
Meghalaya	26.073047	91.872281	S	Satyam Steel Pvt. Ltd.	Cyclical	Steel Mill	PLANT					
Orissa	22.30826	84.764113	S	Adhunik Group	Cyclical	Adhunik Metaliks Ltd.	PLANT	0.45			576	ESTIMATED
Orissa	22.112995	85.374732	A	Shyam Steel Industries Ltd.	Cyclical	Steel Mill	PLANT	0.280			358	ESTIMATED
Orissa	21.683792	85.4358	A	Sree Metaliks Ltd.	Cyclical	Head Office	OFFICE					
Orissa	21.683792	85.4358	S	Sree Metaliks Ltd.	Cyclical	Steel Mill	PLANT	0.12			28	PUBLISHED

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Require-ments (MW)	Electric Requirement Source
Orissa	22.21	84.86	S	Steel Authority of India Ltd.	Cyclical	Rourkela Steel Plant	PLANT	12.6			16118	ESTIMATED
Orissa	21.00	86.02	S	Tata Iron and Steel Co. Ltd.	Cyclical	Tata Steel Plant at Duburi	PLANT	3			3838	ESTIMATED
Orissa	20.943447	86.061403	S	Visa Steel	Cyclical	Steel Mill	PLANT	0.5			75	PUBLISHED
West Bengal	22.496019	88.373489	S	Banga Laxmi Steel Trading Company Ltd.	Cyclical	Corporate Office	OFFICE					
West Bengal	23.506352	87.319192	S	Barjora Steel and Re-Rolling Mills	Cyclical	Steel Mill	PLANT					
West Bengal	22.539922	88.355051	S	Beekay Steel and Power Ltd.	Cyclical	Corporate Office	OFFICE					
West Bengal	22.570969	88.352953	S	Jai Balaji Group	Cyclical	Registered Office	OFFICE					
West Bengal	23.520857	87.309785	A	Jai Balaji Group	Cyclical	Jai Balaji In-dustries Ltd.	PLANT	0.36			461	ESTIMATED
West Bengal	22.546175	88.353214	S	JSW Steel	Cyclical	Corporate Office	OFFICE					
West Bengal	22.583024	88.44938	S	JSW Steel	Cyclical	Corporate Office	OFFICE					
West Bengal	22.93666667	88.386111 11	S		Cyclical	Steel Plant	PLANT					
West Bengal	22.573745	88.431548	S	Shyam Steel Industries Ltd.	Cyclical	Corporate Office	OFFICE		14,000			
West Bengal	23.50855	87.282358	S	Shyam Steel Industries Ltd.	Cyclical	Steel Mill	PLANT	1.1			1000	PUBLISHED
West Bengal	22.545075	88.35502	S	Sree Metaliks Ltd.	Cyclical	Registered Office	OFFICE					
West Bengal	22.568451	88.355946	S	SRMB Steel	Cyclical	Corporate Office	OFFICE			500 - 550		
West Bengal	22.686246	88.290092	A	SRMB Steel	Cyclical	Works	PLANT			500 - 550		

City	Latitude	Longitude	Precision	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Require-ments (MW)	Electric Requirement Source
West Bengal	23.503183	87.307679	A	SRMB Steel	Cyclical	Works	PLANT			500 - 550		
West Bengal	23.55	87.248876	S	Steel Authority of India Ltd.	Cyclical	Durgapur steel plant	PLANT	5.474			7002	ESTIMATED
West Bengal	23.664624	86.916084	S	Steel Authority of India Ltd.	Cyclical	IISCO Steel Plant	PLANT	2.5			3198	ESTIMATED
West Bengal	23.52388889	87.13222222	S	Tirupati Steel	Cyclical	Steel Mill	PLANT					
West Bengal	22.545113	88.353565	S	Visa Steel	Cyclical	Corporate Office	OFFICE					

Table A18. Materials database – Myanmar – steel rebar (ERDC-CERL).

City	Latitude	Longitude	Preci-sion	Company	Industry Type	Site Name	Site Type	Capacity (mil. MTPA)	Employ-ees	Quality	Electric Requirements (MW)	Electric Requirement Source
Yangon	16.81	96.22	A	Myanmar POSCO Steel Co. Ltd.	Cyclical	POSCO Steel Plant	PLANT	0.03			38	ESTIMATED

Table A19. Materials database – Bangladesh – timber (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Barisal	23.28311	89.5051	A			Regular	Ata Danga Baor Wild-life Sanctuary	DEPOSIT		
Barisal	21.89247	90.068	A			Regular	Sundarban Delta	DEPOSIT		
Barisal	21.895	90.4374	A			Regular	Char Kasem	DEPOSIT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Barisal	22.06273	90.3908	A			Regular	Mangrove Forest	DEPOSIT		
Barisal	22.13505	90.3924	A			Regular	Mangrove Forest	DEPOSIT		
Barisal	21.93751	90.6481	A			Regular	Char Kukrimukri	DEPOSIT	2106	
Barisal	21.88759	90.7357	A			Regular	Mangrove Forest	DEPOSIT		
Barisal	22.06625	91.0033	A			Regular	Nijhum Dweep National Park	DEPOSIT		
Chittagong	23.39603	92.1401	A			Regular	Chittagong Hill Tracts (North)	DEPOSIT		
Chittagong	22.79384	92.1824	A			Regular	Kaptai Pulpwood Division	DEPOSIT		
Chittagong	22.2048	92.5167	A			Regular	Bandarban Pulpwood Division	DEPOSIT		
Chittagong	21.48448	92.495	A			Regular	Shangu-Matamuhuri Wildlife Sanctuary: Lama Forest Divison	DEPOSIT		
Chittagong	21.35409	92.0418	A			Regular	Himchari National Park	DEPOSIT	7935	
Chittagong	21.35409	92.0418	A			Regular	Teknaf Game Reserve	DEPOSIT	10225	
Chittagong	21.9079	92.1347	A			Regular	Chunati Wildlife Sanctuary	DEPOSIT	7410	
Chittagong	21.9079	92.1347	A			Regular	Chimbuk Wildlife Sanctuary	DEPOSIT		
Chittagong	22.82844	91.6124	A			Regular	Mixed Evergreen Forest	DEPOSIT		
Chittagong	22.41791	91.7787	A			Regular	Kassalong Hill Forest	DEPOSIT	19190	
Dhaka	24.09086	90.4085	A			Regular	Bhawal National Park	DEPOSIT	5022	
Dhaka	24.33755	90.3256	A			Regular	Kadigarh National Park	DEPOSIT		
Khulna	22.32589	89.5491	A			Regular	The Sundarbans	DEPOSIT	401600	
Khulna	21.89806	89.8016	A			Regular	Sundarban Wildlife Sanctuary (East)	DEPOSIT	23198	
Khulna	21.79895	89.4066	A			Regular	Sundarban Wildlife Sanctuary (South)	DEPOSIT	20094	
Khulna	21.74991	89.2386	A			Regular	Sundarban Wildlife Sanctuary (West)	DEPOSIT	41250	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Khulna	22.66911	89.768	A			Regular	Bagerhat Forest Division	DEPOSIT		
Mymensingh	24.68084	90.103	A			Regular	Madhupur Jungle National Park	DEPOSIT	8438	
Rangpur	25.43173	89.0583	A			Regular	Nawabganj National Park	DEPOSIT		
Rangpur	25.54866	88.9299	A			Regular	Forest	DEPOSIT		
Rangpur	25.54331	88.5515	A			Regular	Dharmarpur Forest	DEPOSIT		
Rangpur	25.66702	88.4892	A			Regular	Ramsagar National Park	DEPOSIT		
Rangpur	25.88981	88.5634	A			Regular	Singra National Park	DEPOSIT		
Rangpur	25.84724	88.6616	A			Regular	Birganj National Park	DEPOSIT		
Rangpur	25.86788	88.7008	A			Regular	Beltoli Shalbon	DEPOSIT		
Rangpur	26.18298	89.0539	A			Regular	Teesta Barrage Park	DEPOSIT		
Rangpur	26.09649	89.1982	A			Regular	Shal Bagan	DEPOSIT		
Sylhet	24.14392	91.4378	A			Regular	Shatchhari National Park	DEPOSIT		
Sylhet	24.12258	91.6309	A			Regular	Rema Kalenga Reserved Forest	DEPOSIT	1795	
Sylhet	24.24413	91.9131	A			Regular	Rajkandi Reserve Forest	DEPOSIT		
Sylhet	24.42444	92.0762	A			Regular	Muraichhara Eco Park	DEPOSIT		
Sylhet	24.6297	92.2205	A			Regular	Madhabkunda Eco Park	DEPOSIT		
Sylhet	24.9994	92.0832	A			Regular	Dalair Haor	DEPOSIT		
Sylhet	24.95836	91.9333	A			Regular	Khadimnagar National Park	DEPOSIT		
Sylhet	25.01363	91.9265	A			Regular	Ratargul Swamp Forest	DEPOSIT		
Sylhet	24.34207	91.7982	A			Regular	Lawachara National Park	DEPOSIT		
Sylhet	24.46463	91.7842	A			Regular	Barshijora Eco Park	DEPOSIT		
Sylhet	24.91714	91.9062	A			Regular	Tilagor Reserve Forest	DEPOSIT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Chittagong	22.33826	91.8443		TK Group of Industries		Regular	Chittagong Office	OFFICE		
Chittagong	22.34784	91.8097		AK Khan Plywood		Regular	Head Office - Chitta-gong	OFFICE		
Dhaka	23.75118	90.3933		TK Group of Industries		Regular	Dhaka Office	OFFICE		
Dhaka	23.7702	90.4063		Partex Star Group		Regular	Corporate Office	OFFICE		
Dhaka	23.79077	90.4043		Amber		Regular	Amber Boards	OFFICE		
Dhaka	23.75399	90.3918		MRS Industries Ltd.		Regular	Dhaka Office	OFFICE		1200
Dhaka	23.79504	90.4266		Safeway Tropi-cal Products		Regular	Corporate Office	OFFICE		11-20
Dhaka	23.78232	90.4164		AK Khan Plywood		Regular	Dhaka Office	OFFICE		
Dhaka	23.72669	90.4191		AKIJ Group		Regular	Corporate Office	OFFICE		1001-5000
Dhaka	23.72694	90.4205		Diamond Particle Board Mills Ltd.		Regular	Corporate Office	OFFICE		
Khulna	23.89791	89.119		Woodland		Regular	Registered Office	OFFICE		50
Rajshahi	24.85475	89.361		Azad Group		Regular	Corporate Office	OFFICE		
Rangpur	25.7718	89.2277		Diamond Particle Board Mills Ltd.		Regular	Corporate Office	OFFICE		
Barisal	21.98312	90.2225		Saw Mill		Regular		PLANT		
Barisal	21.9523	90.2599		Baliyatoli Saw Mill		Regular		PLANT		
Barisal	22.06043	90.3203		Gazi Bari Saw Mill		Regular		PLANT		
Barisal	22.18058	90.3632		Saw Mill Sonakhali		Regular		PLANT		
Barisal	22.1806	90.3632		Julekhara Bazar Saw Mill 1		Regular		PLANT		
Barisal	22.26125	90.336		Badura Saw Mill		Regular		PLANT		
Barisal	22.71364	90.3616		Saw Mill		Regular		PLANT		
Barisal	22.76349	90.3936		Howlader Saw and Rice Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Barisal	22.84765	90.277		Seyam Sefat Saw Mill		Regular		PLANT		
Barisal	22.86884	90.3206		Saw Mill		Regular		PLANT		
Chittagong	22.33909	91.8127		HK Timber		Regular		PLANT	50000 - 100000	
Chittagong	21.84229	92.0636		Saw Mill		Regular		PLANT		
Chittagong	22.05282	92.1103		Al Safa Saw Mill		Regular		PLANT		
Chittagong	22.3281	91.8356		Star Saw Mill		Regular		PLANT		
Chittagong	22.38876	91.8621		Zilani Saw Mill		Regular		PLANT		
Chittagong	22.88653	91.5365		Sobura Timber and Saw Mill		Regular		PLANT		
Chittagong	22.89954	91.5337		Saw Mill		Regular		PLANT		
Chittagong	23.15307	91.4736		Saw Mill		Regular		PLANT		
Chittagong	22.9017	91.403		Mita Saw Mill		Regular		PLANT		
Chittagong	22.86465	91.2605		Bhai Bhai Saw Mill		Regular		PLANT		
Chittagong	22.81815	90.8332		Ruhul Amin Saw Mill		Regular		PLANT		
Chittagong	22.98571	91.0215		Golam Sarwar Saw Mill		Regular		PLANT		
Chittagong	23.08945	90.9605		Bodolkot Saw Mill		Regular		PLANT		
Chittagong	23.13578	90.7862		Rupsa Wood Saw Mill		Regular		PLANT		
Chittagong	23.13492	90.7832		Shahid and Brothers Saw Mill		Regular		PLANT		
Chittagong	23.22201	91.2377		Ma Saw Mill		Regular		PLANT		
Chittagong	23.44018	91.0501		Shakil Enter-prise and Auto Saw Mill		Regular		PLANT		
Chittagong	23.44491	91.0848		Dhanuakhala Saw Mill		Regular		PLANT		
Chittagong	23.51969	91.0914		Salim Auto Saw Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Chittagong	23.66062	90.8468		Kashipur Timber and Saw Mill		Regular		PLANT		
Chittagong	23.68365	90.7789		Faruq Saw Mill		Regular		PLANT		
Chittagong	22.38173	91.8646		AK Khan Plywood		Regular		PLANT		
Dhaka	23.8025	90.3746		Comilla Crop Saw Mill		Regular		PLANT		
Dhaka	23.82244	90.3651		Kamal Timber and Saw Mill		Regular		PLANT		
Dhaka	23.82244	90.3651		Motlob Timber and Saw Mill		Regular		PLANT		
Dhaka	23.82244	90.3651		New Chittagong Saw Mill		Regular		PLANT		
Dhaka	23.82882	90.3902		Ahmed Timber Complex and Saw Mill		Regular		PLANT		
Dhaka	23.78611	90.4263		GM Timber		Regular		PLANT		
Dhaka	23.69431	90.4893		Raj Timber and Saw Mill		Regular		PLANT		
Dhaka	23.81896	90.4148		New Quality Timber and Saw Mill		Regular		PLANT		
Dhaka	23.71806	90.4221		Chittagong Timber Works		Regular		PLANT		
Dhaka	22.32447	91.8246		HK Timber		Regular		PLANT		21-50
Dhaka	23.77176	90.3562		Quality Timber Ind. Ltd.		Regular		PLANT		101-200
Dhaka	23.74428	90.3797		Marzuk International		Regular		PLANT		21-50
Dhaka	23.72624	90.435		Gumati Timber Complex Ltd.		Regular		PLANT		51-100
Dhaka	23.74953	90.4263		Nannu Timber and Saw Mill		Regular		PLANT		
Dhaka	23.71052	90.4363		Tauhid Saw Mill		Regular		PLANT		
Dhaka	23.85693	90.4066		Chittagong Timber Traders and Saw Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Dhaka	23.85706	90.4066		National Timber and Saw Mill		Regular		PLANT		
Dhaka	23.76041	90.352		Welcome Timber and Saw Mill		Regular		PLANT		
Dhaka	23.81215	90.3945		Mahbub Saw Mill		Regular		PLANT		
Dhaka	23.79484	90.3735		Shah Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85377	90.26		Akhil Timber, Saw Mill and Furniture		Regular		PLANT		
Dhaka	23.85362	90.2599		Tangail Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85352	90.2599		New Rajdhani Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85372	90.2599		Goni Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85532	90.2603		Taru Bepari and Sons Saw Mill		Regular		PLANT		
Dhaka	23.85382	90.26		Nagarpur Timber and Saw Mill		Regular		PLANT		
Dhaka	23.83619	90.2591		New Savar Timber and Saw Mill		Regular		PLANT		
Dhaka	23.65654	90.5181		Doi Nong Saw Mill		Regular		PLANT		
Dhaka	23.83614	90.259		Ramij Uddin Timber Traders and Saw Mill		Regular		PLANT		
Dhaka	23.83739	90.2587		New Anandapur Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85289	90.2595		Kazi Timber Saw Mill and Furniture Traders		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Dhaka	23.83649	90.2589		Chittagong Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85197	90.2592		Rangamati Friends Timber and Saw Mill		Regular		PLANT		
Dhaka	23.85305	90.2596		Sajan Timber and Saw Mill		Regular		PLANT		
Dhaka	24.0474	90.8636		Abul Khaer Saw Mill		Regular		PLANT		
Dhaka	23.60539	90.4572		Boktaboli Bazar Saw Mill		Regular		PLANT		
Dhaka	24.33282	90.2454		Saw Mill		Regular		PLANT		
Dhaka	23.58132	90.1434		Siraj Saw Mill		Regular		PLANT		
Dhaka	23.65845	90.1328		Dhapari Bazar Saw Mill		Regular		PLANT		
Dhaka	23.55785	90.4345		Bismillah Saw Mill		Regular		PLANT		
Dhaka	24.10193	90.9262		Akbarnagar Saw Mill		Regular		PLANT		
Dhaka	24.03465	90.7354		Faruk Saw Mill and Timber		Regular		PLANT		
Dhaka	23.61105	90.467		Sawrov Saw Mill		Regular		PLANT		
Dhaka	23.55837	90.4298		Taltala Timber and Saw Mill		Regular		PLANT		
Dhaka	23.55728	90.4348		Bhuiyan Saw Mill		Regular		PLANT		
Dhaka	23.54311	90.4716		Abdulapr Saw Mill		Regular		PLANT		
Dhaka	23.30126	89.919		Saw Mill		Regular		PLANT		
Dhaka	23.28104	89.7723		Dablu Saw Mill		Regular		PLANT		
Dhaka	23.36703	89.814		Saw Mill		Regular		PLANT		
Dhaka	23.54248	89.8606		Saw Mill		Regular		PLANT		
Dhaka	23.61299	89.8558		Babul Saw Mill		Regular		PLANT		
Dhaka	23.76763	89.6481		Kazi Saw Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Dhaka	23.59754	90.6083		TK Group of Industries	Particle Board, Plywood, Veneer	Regular	Super Board Mills Ltd.	PLANT		400
Dhaka	23.68151	90.5335		Partex Star Group	Particle Board, Plywood, Veneer	Regular	Star Particle Board Mills Ltd.	PLANT		
Dhaka	23.75218	90.3954		Bengal Plywood Mills Ltd.	Plywood	Regular	Bengal Plywood Mills Ltd.	PLANT		300
Dhaka	23.76298	90.4075		Safeway Tropical Products		Regular	Factory	PLANT		
Dhaka	23.77573	90.366		Safeway Tropical Products		Regular	Drying Center	PLANT		
Dhaka	23.8564	89.9587		AKIJ Group	Particle Board	Regular	AKIJ Particle Board Mills Ltd	PLANT		
Khulna	22.80633	89.5772		Star Saw Mill and Timber		Regular		PLANT		
Khulna	23.74648	88.6869		Khan Saw Mill		Regular		PLANT		
Khulna	23.68639	89.1739		Saw Mill		Regular		PLANT		
Khulna	23.6029	88.7769		Saw Mill		Regular		PLANT		
Khulna	23.60221	88.7806		Bus Stand Saw Mill		Regular		PLANT		
Khulna	23.54567	89.149		Saw Mill		Regular		PLANT		
Khulna	23.25598	89.2973		Mondol Saw Mill		Regular		PLANT		
Khulna	23.18682	89.3828		Taj Saw and Rice Mill		Regular		PLANT		
Khulna	23.12804	89.2942		Saw Mill		Regular		PLANT		
Khulna	23.12722	89.287		Ahmed Saw Mill		Regular		PLANT		
Khulna	23.12839	89.2855		Bottola Saw Mill		Regular		PLANT		
Khulna	23.12837	89.2844		Zalil Saw Mill		Regular		PLANT		
Khulna	23.12837	89.2844		Globe Saw Mill		Regular		PLANT		
Khulna	23.15832	89.2311		Shawdagar Saw Mill		Regular		PLANT		
Khulna	23.17931	89.2213		Molla Saw Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Khulna	23.1634	89.1915		Dharmatala Saw Mill		Regular		PLANT		
Khulna	23.15975	89.1794		Zamtola Saw Mill		Regular		PLANT		
Khulna	23.05789	88.9941		Blue Saw Mill		Regular		PLANT		
Khulna	22.90904	89.073		Billal Saw Mill		Regular		PLANT		
Khulna	22.68984	89.0347		Soto's Saw Mill		Regular		PLANT		
Khulna	22.79004	89.4819		North Khulna Saw Mill		Regular		PLANT		
Khulna	22.8726	89.4917		Bypass Saw Mill		Regular		PLANT		
Khulna	23.88271	89.099		MRS Industries Ltd.		Regular		PLANT		
Khulna	23.89791	89.119		Woodland	Particle Board, Plywood	Regular	Registered Factory	PLANT		
Mymensingh	24.66248	90.8441		Saw Mill		Regular		PLANT		
Mymensingh	24.7479	90.4079		Saw Mill		Regular		PLANT		
Mymensingh	24.75892	90.39		Saw Mill		Regular		PLANT		
Mymensingh	24.92107	89.9564		Saw Mill		Regular		PLANT		
Mymensingh	24.65316	89.9041		Roton Saw Mill		Regular		PLANT		
Mymensingh	24.65263	89.9029		Korim Saw Mill		Regular		PLANT		
Mymensingh	24.61805	89.8904		Jamal Saw Mill		Regular		PLANT		
Mymensingh	24.56574	89.9266		Hay Saw Mill and Furniture		Regular		PLANT		
Mymensingh	24.47703	90.0578		Makrai Saw Mill		Regular		PLANT		
Mymensingh	24.47491	90.0594		Makrai Saw Mill		Regular		PLANT		
Mymensingh	24.39662	89.9952		Adarsha Saw Mill		Regular		PLANT		
Mymensingh	24.33282	90.2454		Saw Mill		Regular		PLANT		
Mymensingh	24.45603	90.546		Saw Mill		Regular		PLANT		
Mymensingh	24.27358	90.5476		Saw Mill		Regular		PLANT		
Rajshahi	24.90658	89.0825		Saw Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Rajshahi	24.78985	88.8857		Khori Saw Mill		Regular		PLANT		
Rajshahi	24.72764	88.2893		Azom Saw Mill		Regular		PLANT		
Rajshahi	24.62695	88.1987		Asif Alif Saw Mill		Regular		PLANT		
Rajshahi	24.36575	88.6369		Selim Saw Mill		Regular		PLANT		
Rajshahi	24.36438	88.6672		Dewanpara Saw Mill		Regular		PLANT		
Rajshahi	24.41373	88.9971		Saw Mill Natore		Regular		PLANT		
Rajshahi	24.13291	89.0638		Karmokar Para Saw Mill		Regular		PLANT		
Rajshahi	24.07284	89.0565		Badal Saw Mill		Regular		PLANT		
Rajshahi	23.88669	89.4906		Chad Molar Saw Mill		Regular		PLANT		
Rajshahi	23.89719	89.6411		Saw Mill		Regular		PLANT		
Rajshahi	24.40401	89.5985		Ajit Saw Mill		Regular		PLANT		
Rajshahi	24.65094	89.4256		Dharmokam Saw Mill		Regular		PLANT		
Rajshahi	24.65178	89.4252		Altab Ali Saw Mill		Regular		PLANT		
Rajshahi	24.65396	89.4243		Sherula Bottola Saw Mill		Regular		PLANT		
Rajshahi	24.67608	89.413		Satto Gosh Saw Mill		Regular		PLANT		
Rajshahi	24.67641	89.4136		Prince Saw Mill		Regular		PLANT		
Rajshahi	24.67733	89.4127		Johurul Saw Mill		Regular		PLANT		
Rajshahi	24.65799	89.3529		Belghoria Saw Mill		Regular		PLANT		
Rajshahi	24.90953	89.3532		Saw Mill and Furniture Store		Regular		PLANT		
Rangpur	26.03615	88.4181		Arif and Broth-ers Saw Mill		Regular		PLANT		
Rangpur	25.85977	88.6494		Saha Saw Mill		Regular		PLANT		
Rangpur	25.75013	89.2305		Ajim Uddin Saw Mill		Regular		PLANT		
Rangpur	25.61306	89.2752		Jaigir Hat Saw Mill		Regular		PLANT		

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (hectares)	Employees
Rangpur	25.42817	89.378		Saw Mill		Regular		PLANT		
Rangpur	25.30109	89.4222		Chowdhury Saw Mill		Regular		PLANT		
Rangpur	25.28505	89.0047		Hili Boro Mill		Regular		PLANT		
Sylhet	24.36968	91.4113		Jonata Saw Mill		Regular		PLANT		
Sylhet	24.32946	91.5381		Vadesshor Saw Mill		Regular		PLANT		
Sylhet	24.49539	92.0185		A Aziz Saw Mill		Regular		PLANT		
Sylhet	24.70317	92.1926		Shamim Saw Mill		Regular		PLANT		
Sylhet	24.92669	91.4969		Shabnaj Saw Mill		Regular		PLANT		
Rangpur	25.77012	89.0936	C		Particle Board	Regular	GENERAL PARTICLE BOARD AREA	PLANT		
Rajshahi	24.79721	89.3628	C		Particle Board	Regular	GENERAL PARTICLE BOARD AREA	PLANT		
Khulna	23.86688	89.1977	C		Particle Board, Ply-wood	Regular	GENERAL PLYWOOD/PARTICLE BOARD AREA	PLANT		
Dhaka	23.71621	90.4559	C		Particle Board, Ply-wood, Ve-neer	Regular	GENERAL VENEER/ PLYWOOD/PARTICLE BOARD AREA	PLANT		
Chittagong	22.34754	91.8237	C		Plywood	Regular	GENERAL PLYWOOD AREA	PLANT		

Table A20. Materials database – Bangladesh – aggregate (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Barisal	21.939508	89.648903	A			Regular		DEPOSIT	
Barisal	22.457867	90.870592	A		Clay	Regular	Ganges River Delta Clay	DEPOSIT	
Chittagong	23.228659	91.311407	A		Sand	Regular	Chauddagram Sand	DEPOSIT	
Chittagong	23.00081	92.250249	A		Gravel	Regular	Chittagong Hill Gravel	DEPOSIT	1

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chittagong	22.298228	91.998402	A		Clay	Regular	Haidgaon, Chittagong White Clay	DEPOSIT	
Chittagong	22.120522	92.1095	A		Clay	Regular	Baitul Izzat, Satkania upazila White Clay	DEPOSIT	
Dhaka	23.750453	90.394544	A	Maddhapara Granite Mining Co. Ltd.	Stone	Regular	Dhaka Office	OFFICE	
Dhaka	23.77888889	90.33861111	A		Sand	Regular	Gabtoli Sand Yard	PLANT	
Dhaka	23.733593	90.583396	A		Stone	Regular	Utma - Black Stone	DEPOSIT	
Dhaka	23.77611111	90.33638889	A		Stone	Regular	Gabtoli Stone Crusher Area	PLANT	
Dhaka	24.056192	89.735115	A			Regular		DEPOSIT	
Khulna	23.089478	90.515305	A			Regular		DEPOSIT	
Khulna	23.025307	90.54924	A			Regular		DEPOSIT	
Mymensingh	25.363487	89.708291	A			Regular		DEPOSIT	
Mymensingh	25.288166	89.720108	A			Regular		DEPOSIT	
Mymensingh	25.119906	89.661246	A			Regular		DEPOSIT	
Mymensingh	24.770983	89.765274	A			Regular		DEPOSIT	
Mymensingh	24.71316	89.711838	A			Regular		DEPOSIT	
Mymensingh	24.74819	89.781654	A			Regular		DEPOSIT	
Mymensingh	24.716097	89.764091	A			Regular		DEPOSIT	
Mymensingh	25.020206	90.011461	A		Sand	Regular	Baljiuri Sand	DEPOSIT	
Mymensingh	25.025393	90.020584	A		Sand	Regular	Sherpur Sand	DEPOSIT	
Mymensingh	25.146698	90.662797	A		Clay	Regular	Bijoypur, Netronka White Clay	DEPOSIT	
Mymensingh	24.560936	89.837987	A		Clay	Regular	Gopalpur, Netronka White Clay	DEPOSIT	
Mymensingh	25.089038	90.192364	A		Clay	Regular	Nalitabari, Sherpur White Clay	DEPOSIT	
Rajshahi	25.910063	89.82032	A			Regular		DEPOSIT	
Rajshahi	25.910063	89.82032	A			Regular		DEPOSIT	
Rajshahi	25.119906	89.661246	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Rajshahi	25.021052	89.616569	A			Regular		DEPOSIT	
Rajshahi	25.001198	89.621514	A			Regular		DEPOSIT	
Rajshahi	24.996352	89.602065	A			Regular		DEPOSIT	
Rajshahi	24.98989	89.623146	A			Regular		DEPOSIT	
Rajshahi	24.354134	89.748856	A			Regular		DEPOSIT	
Rajshahi	25.92874	89.87896	A			Regular		DEPOSIT	
Rajshahi	25.044333	88.762806	A		Clay	Regular	Patnitala, Naogaon White Clay	DEPOSIT	
Rangpur	25.567837	89.062043	A	Maddhapara Granite Mining Co. Ltd.	Stone	Regular	Maddharapara Granite Mine	DEPOSIT	1.65
Rangpur	25.548035	88.960769	A		Sand	Regular	Barapukuria Sand	DEPOSIT	90
Rangpur	25.5685	89.066076	A	Maddhapara Granite Mining Co. Ltd.	Sand	Regular	Maddharapara Sand	DEPOSIT	17.25
Rangpur	25.555041	88.618844	A		Sand	Regular	Dighipara Sand	DEPOSIT	
Rangpur	26.357683	89.007274	A		Gravel	Regular	Patgram Gravel	DEPOSIT	2.5
Rangpur	26.518346	88.44062	A		Gravel	Regular	Tetulia Gravel	DEPOSIT	2.5
Rangpur	26.189823	89.016388	A			Regular		DEPOSIT	
Rangpur	26.134683	89.08165	A			Regular		DEPOSIT	
Rangpur	25.94095	89.202767	A			Regular		DEPOSIT	
Rangpur	25.906611	89.228942	A			Regular		DEPOSIT	
Rangpur	25.910063	89.82032	A			Regular		DEPOSIT	
Rangpur	25.791145	89.740547	A			Regular		DEPOSIT	
Rangpur	25.782659	89.803299	A			Regular		DEPOSIT	
Rangpur	25.757012	89.746041	A			Regular		DEPOSIT	
Rangpur	25.713748	89.810501	A			Regular		DEPOSIT	
Rangpur	25.704591	89.775269	A			Regular		DEPOSIT	
Rangpur	25.620099	89.533554	A			Regular		DEPOSIT	
Rangpur	25.635718	89.801367	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Rangpur	25.650393	89.742347	A			Regular		DEPOSIT	
Rangpur	25.572551	89.738525	A			Regular		DEPOSIT	
Rangpur	25.515772	89.797425	A			Regular		DEPOSIT	
Rangpur	25.460648	89.75599	A			Regular		DEPOSIT	
Rangpur	25.452807	89.714447	A			Regular		DEPOSIT	
Rangpur	25.358248	89.675682	A			Regular		DEPOSIT	
Rangpur	25.411707	89.673889	A			Regular		DEPOSIT	
Rangpur	25.20371	89.628746	A			Regular		DEPOSIT	
Rangpur	25.176872	89.688507	A			Regular		DEPOSIT	
Rangpur	25.067685	89.597374	A			Regular		DEPOSIT	
Rangpur	25.073088	89.638603	A			Regular		DEPOSIT	
Rangpur	25.72922897	89.82205963	A			Regular		DEPOSIT	
Rangpur	25.547369	88.960472	A		Clay	Regular	Maddhapara, Barapukuria White Clay	DEPOSIT	
Rangpur	25.555037	88.618888	A		Clay	Regular	Dighipara, Dinajpur White Clay	DEPOSIT	
Sylhet	24.642379	91.978351	A		Sand	Regular	Bhatera Sand	DEPOSIT	8
Sylhet	24.244282	91.376338	A		Sand	Regular	Shahajibazar Sand	DEPOSIT	0.3
Sylhet	24.341583	91.537335	A		Sand	Regular	Bahubal Sand	DEPOSIT	0.17
Sylhet	25.133435	92.121134	A		Sand	Regular	Jaintapur Sand	DEPOSIT	
Sylhet	25.104914	92.176409	A		Sand	Regular	Lalakhal Sand	DEPOSIT	
Sylhet	25.073673	91.398618	A		Sand	Regular	Shunamganj Sand	DEPOSIT	
Sylhet	24.599899	91.729893	A		Sand	Regular	Fajilpur Sand	DEPOSIT	
Sylhet	25.081065	91.149883	A		Sand	Regular	Sripur Sand	DEPOSIT	
Sylhet	25.165065	92.016485	A		Stone	Regular	Jaflong - White Stone	DEPOSIT	
Sylhet	24.658372	91.823518	A		Stone	Regular	Volagonj - Black and White Stone	DEPOSIT	
Sylhet	25.169708	91.886101	A		Stone	Regular	Bistakandi - Gray Stone	DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Sylhet	24.978516	92.345528	A		Stone	Regular	Sharfin - Red Stone	DEPOSIT	
Sylhet	25.159596	91.742674	A		Stone	Regular	Bholaganj Stone	DEPOSIT	
Sylhet	25.159559	91.742773	A		Gravel	Regular	Bholaganj Gravel	DEPOSIT	4

Table A21. Materials database – India – aggregate (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Assam	27.91921616	95.61668396	A			Regular		DEPOSIT	
Assam	27.80580711	95.67269897	A			Regular		DEPOSIT	
Assam	27.77583122	95.73802185	A			Regular		DEPOSIT	
Assam	27.79335403	95.62683105	A			Regular		DEPOSIT	
Assam	27.75016785	95.34482574	A			Regular		DEPOSIT	
Assam	27.64651108	95.12593079	A			Regular		DEPOSIT	
Assam	27.6641407	95.06829834	A			Regular		DEPOSIT	
Assam	27.61238289	95.02725983	A			Regular		DEPOSIT	
Assam	27.63211823	94.9932785	A			Regular		DEPOSIT	
Assam	27.64072037	95.0078125	A			Regular		DEPOSIT	
Assam	27.59156609	94.97662354	A			Regular		DEPOSIT	
Assam	27.54629326	94.92795563	A			Regular		DEPOSIT	
Assam	27.53854561	94.86693573	A			Regular		DEPOSIT	
Assam	27.51992607	94.87277222	A			Regular		DEPOSIT	
Assam	27.51445389	94.92015839	A			Regular		DEPOSIT	
Assam	27.46337128	94.78551483	A			Regular		DEPOSIT	
Assam	27.43793106	94.79109192	A			Regular		DEPOSIT	
Assam	27.41555405	94.75624847	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Assam	27.33727837	94.69606781	A			Regular		DEPOSIT	
Assam	27.32809258	94.66114044	A			Regular		DEPOSIT	
Assam	27.28078842	94.6741333	A			Regular		DEPOSIT	
Assam	27.27474213	94.64283752	A			Regular		DEPOSIT	
Assam	27.25333977	94.60308838	A			Regular		DEPOSIT	
Assam	27.23483086	94.64819336	A			Regular		DEPOSIT	
Assam	27.21746254	94.60449982	A			Regular		DEPOSIT	
Assam	27.20820045	94.62465668	A			Regular		DEPOSIT	
Assam	27.19766045	94.58712769	A			Regular		DEPOSIT	
Assam	27.18154526	94.58545685	A			Regular		DEPOSIT	
Assam	26.97119331	94.36843872	A			Regular		DEPOSIT	
Assam	26.9322567	94.33773041	A			Regular		DEPOSIT	
Assam	26.90842247	94.33176422	A			Regular		DEPOSIT	
Assam	26.89502716	94.25387573	A			Regular		DEPOSIT	
Assam	26.8972683	94.15525055	A			Regular		DEPOSIT	
Assam	26.8820076	94.20248413	A			Regular		DEPOSIT	
Assam	26.87177467	94.07492828	A			Regular		DEPOSIT	
Assam	26.86519432	94.13033295	A			Regular		DEPOSIT	
Assam	26.8416748	94.0740509	A			Regular		DEPOSIT	
Assam	26.83184242	93.96861267	A			Regular		DEPOSIT	
Assam	26.78258705	93.77317047	A			Regular		DEPOSIT	
Assam	26.79108429	93.83024597	A			Regular		DEPOSIT	
Assam	26.71671486	89.42099762	A			Regular		DEPOSIT	
Assam	26.77921867	93.86743164	A			Regular		DEPOSIT	
Assam	26.77412224	93.51005554	A			Regular		DEPOSIT	
Assam	26.76729393	93.67718506	A			Regular		DEPOSIT	
Assam	26.76861954	93.56336975	A			Regular		DEPOSIT	
Assam	26.75868607	93.60222626	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Assam	26.74925995	93.42044067	A			Regular		DEPOSIT	
Assam	26.72747993	93.36782074	A			Regular		DEPOSIT	
Assam	26.72930908	93.61907196	A			Regular		DEPOSIT	
Assam	26.7237339	93.65498352	A			Regular		DEPOSIT	
Assam	26.62950134	92.91264343	A			Regular		DEPOSIT	
Assam	26.62974358	92.95424652	A			Regular		DEPOSIT	
Assam	26.60468102	92.82540131	A			Regular		DEPOSIT	
Assam	26.615839	92.95761108	A			Regular		DEPOSIT	
Assam	26.60055351	92.87993622	A			Regular		DEPOSIT	
Assam	26.60092735	92.71219635	A			Regular		DEPOSIT	
Assam	26.59285545	92.78057861	A			Regular		DEPOSIT	
Assam	26.58554649	92.60281372	A			Regular		DEPOSIT	
Assam	26.5925808	92.73776245	A			Regular		DEPOSIT	
Assam	26.57918549	92.693573	A			Regular		DEPOSIT	
Assam	26.58313751	92.82640839	A			Regular		DEPOSIT	
Assam	26.56951523	92.66364288	A			Regular		DEPOSIT	
Assam	26.56278229	92.39200592	A			Regular		DEPOSIT	
Assam	26.5583725	92.50531006	A			Regular		DEPOSIT	
Assam	26.55820084	92.68878937	A			Regular		DEPOSIT	
Assam	26.53016281	92.64554596	A			Regular		DEPOSIT	
Assam	26.54915428	92.46842194	A			Regular		DEPOSIT	
Assam	26.54914665	92.3854599	A			Regular		DEPOSIT	
Assam	26.53941917	92.59637451	A			Regular		DEPOSIT	
Assam	26.54268837	92.53656769	A			Regular		DEPOSIT	
Assam	26.53414917	92.49131012	A			Regular		DEPOSIT	
Assam	26.51614761	92.59281921	A			Regular		DEPOSIT	
Assam	26.48389435	92.26476288	A			Regular		DEPOSIT	
Assam	26.44070625	92.16215515	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Assam	26.46221161	92.20804596	A			Regular		DEPOSIT	
Assam	26.4589119	92.25440216	A			Regular		DEPOSIT	
Assam	26.44460106	92.236763	A			Regular		DEPOSIT	
Assam	26.44470978	92.20298767	A			Regular		DEPOSIT	
Assam	26.43084145	92.25397491	A			Regular		DEPOSIT	
Assam	26.41431618	92.1156311	A			Regular		DEPOSIT	
Assam	26.35827637	92.115448	A			Regular		DEPOSIT	
Assam	26.39720726	92.08952332	A			Regular		DEPOSIT	
Assam	26.38707352	92.09489441	A			Regular		DEPOSIT	
Assam	26.32003593	91.97891235	A			Regular		DEPOSIT	
Assam	26.31598473	92.05157471	A			Regular		DEPOSIT	
Assam	26.26767349	91.95193481	A			Regular		DEPOSIT	
Assam	26.263237	91.90112305	A			Regular		DEPOSIT	
Assam	26.25153351	91.86173248	A			Regular		DEPOSIT	
Assam	26.22518349	90.50637054	A			Regular		DEPOSIT	
Assam	26.2329216	91.86174011	A			Regular		DEPOSIT	
Assam	26.22215652	90.44300842	A			Regular		DEPOSIT	
Assam	26.21757507	91.77793121	A			Regular		DEPOSIT	
Assam	26.21314049	91.20391083	A			Regular		DEPOSIT	
Assam	26.2001915	91.1869278	A			Regular		DEPOSIT	
Assam	26.20514679	91.34862518	A			Regular		DEPOSIT	
Assam	26.21499443	90.47839355	A			Regular		DEPOSIT	
Assam	26.22093391	91.84533691	A			Regular		DEPOSIT	
Assam	26.18308258	91.1471405	A			Regular		DEPOSIT	
Assam	26.1796093	91.2508316	A			Regular		DEPOSIT	
Assam	26.19869041	90.60043335	A			Regular		DEPOSIT	
Assam	26.14705467	91.03186798	A			Regular		DEPOSIT	
Assam	26.17905045	91.11164093	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Assam	26.19795227	91.15966034	A			Regular		DEPOSIT	
Assam	26.16241264	90.4107132	A			Regular		DEPOSIT	
Assam	26.18118858	90.29392242	A			Regular		DEPOSIT	
Assam	26.17969131	90.7175293	A			Regular		DEPOSIT	
Assam	26.1748333	91.61068726	A			Regular		DEPOSIT	
Assam	26.174963	90.34591675	A			Regular		DEPOSIT	
Assam	26.1556778	90.21000671	A			Regular		DEPOSIT	
Assam	26.1635952	91.21414948	A			Regular		DEPOSIT	
Assam	26.16833687	90.68536377	A			Regular		DEPOSIT	
Assam	26.13581085	90.27013397	A			Regular		DEPOSIT	
Assam	26.16405106	91.4367218	A			Regular		DEPOSIT	
Assam	26.15993309	91.27922058	A			Regular		DEPOSIT	
Assam	26.1424675	91.52988434	A			Regular		DEPOSIT	
Assam	26.15706825	91.31507874	A			Regular		DEPOSIT	
Assam	26.14657974	90.80089569	A			Regular		DEPOSIT	
Assam	26.14523888	90.10161591	A			Regular		DEPOSIT	
Assam	26.14579582	91.24860382	A			Regular		DEPOSIT	
Assam	26.14426994	90.76538086	A			Regular		DEPOSIT	
Assam	26.1345005	90.68480682	A			Regular		DEPOSIT	
Assam	26.13414574	90.74485779	A			Regular		DEPOSIT	
Assam	26.12110329	90.83411407	A			Regular		DEPOSIT	
Assam	26.12191772	90.76582336	A			Regular		DEPOSIT	
Assam	26.09500504	90.07021332	A			Regular		DEPOSIT	
Assam	26.07641411	90.13568115	A			Regular		DEPOSIT	
Assam	26.07500648	90.19570923	A			Regular		DEPOSIT	
Assam	26.07335854	90.16622925	A			Regular		DEPOSIT	
Assam	26.05469894	90.02485657	A			Regular		DEPOSIT	
Assam	26.04039192	90.11444092	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Assam	26.00049019	89.96409607	A			Regular		DEPOSIT	
Assam	25.94498062	89.90921021	A			Regular		DEPOSIT	
Assam	25.92624474	89.88809967	A			Regular		DEPOSIT	
Assam	25.8985424	89.89409637	A			Regular		DEPOSIT	
Assam	25.8920269	89.92786407	A			Regular		DEPOSIT	
Assam	25.82202148	89.89839935	A			Regular		DEPOSIT	
Assam	27.37333333	95.95027778	A		Stone	Regular	Stone Quarry	DEPOSIT	
Assam	24.84111111	92.81361111	A		Sand	Regular	Sand Quarry	DEPOSIT	
Chattisgarh	21.52689	83.316707	A	Steel Authority of India	Stone	Regular	Hirri Mine	DEPOSIT	
Chhattisgarh	22.58710098	82.57107544	A			Regular		DEPOSIT	
Chhattisgarh	22.47286606	82.68783569	A			Regular		DEPOSIT	
Chhattisgarh	22.38171577	82.70540619	A			Regular		DEPOSIT	
Chhattisgarh	22.29157829	82.70362091	A			Regular		DEPOSIT	
Chhattisgarh	22.17934227	82.66371155	A			Regular		DEPOSIT	
Chhattisgarh	22.14783669	82.64590454	A			Regular		DEPOSIT	
Chhattisgarh	22.10659409	82.6476059	A			Regular		DEPOSIT	
Chhattisgarh	21.77749062	82.73629761	A			Regular		DEPOSIT	
Chhattisgarh	21.72241783	83.14061737	A			Regular		DEPOSIT	
Chhattisgarh	21.72736931	82.48444366	A			Regular		DEPOSIT	
Chhattisgarh	21.72381592	82.95381165	A			Regular		DEPOSIT	
Chhattisgarh	21.72352219	82.98685455	A			Regular		DEPOSIT	
Chhattisgarh	21.70595551	82.91590118	A			Regular		DEPOSIT	
Chhattisgarh	21.67324638	83.32806396	A			Regular		DEPOSIT	
Chhattisgarh	21.56611633	82.36086273	A			Regular		DEPOSIT	
Chhattisgarh	21.33851814	82.17375946	A			Regular		DEPOSIT	
Chhattisgarh	20.95560646	81.88433838	A			Regular		DEPOSIT	
Chhattisgarh	19.1883831	80.39930725	A			Regular		DEPOSIT	
Chhattisgarh	19.10637856	80.34632874	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Chhattisgarh	19.01684189	80.30456543	A			Regular		DEPOSIT	
Chhattisgarh	21.09694444	82.22722222	A	Granite Mining Area	Stone	Regular	Granite Mine	DEPOSIT	
Jharkhand	22.790731	86.153587	A	Gajanan Minerals		Regular	Gajanan Minerals Mine	DEPOSIT	
Jharkhand	22.28863144	86.66539764	A			Regular		DEPOSIT	
Jharkhand	24.186873	83.654546	A		Stone	Regular	Garhwa Mine	DEPOSIT	14.93
Jharkhand	24.264705	83.593786	A		Stone	Regular	Palamu Mine	DEPOSIT	14.93
Jharkhand	24.27557	87.253244	A		Stone	Regular	Dumka Mine	DEPOSIT	3.821
Jharkhand	24.832009	87.233328	A		Stone	Regular	Godda Mine	DEPOSIT	3.821
Jharkhand	24.476024	86.691022	A		Stone	Regular	Deogarh Mine	DEPOSIT	3.821
Jharkhand	23.34724	85.30621	A		Stone	Regular	Ranchi Mine	DEPOSIT	3.821
Jharkhand	24.042162	84.083018	A		Stone	Regular	Daltonganj Mine	DEPOSIT	3.821
Jharkhand	24.27557	87.253244	A		Sand	Regular	Dumka Mine	DEPOSIT	22.74
Jharkhand	24.476024	86.691022	A		Sand	Regular	Deogarh Mine	DEPOSIT	22.74
Jharkhand	24.264705	83.593786	A		Sand	Regular	Palamu Mine	DEPOSIT	22.74
Jharkhand	22.870003	85.451987	A		Sand	Regular	Singhbhum Mine	DEPOSIT	22.74
Jharkhand	23.996224	85.369318	A		Sand	Regular	Hazaribagh Mine	DEPOSIT	22.74
Jharkhand	25.24969	87.627697	A		Sand	Regular	Sahidganj Mine	DEPOSIT	22.74
Jharkhand	24.367359	83.559275	A	Steel Authority of India	Stone	Regular	Bhawanathpur & Tulsidamar Mine	DEPOSIT	
Meghalaya	25.64666667	89.96944444	A		Stone	Regular	Stone Quarry	DEPOSIT	
Meghalaya	25.65388889	89.95888889	A		Stone	Regular	Stone Quarry	DEPOSIT	
Meghalaya	25.65611111	89.95388889	A		Stone	Regular	Stone Quarry	DEPOSIT	
Meghalaya	25.66305556	89.94944444	A		Stone	Regular	Stone Quarry	DEPOSIT	
Meghalaya	25.165036	92.379695	A	Star Cement	Stone	Regular	Meghalaya Mineral Mine	DEPOSIT	
Odissa	20.380064	85.524321	A	A. N. Patnaik	Stone	Regular	Banki Mine	DEPOSIT	
Odissa	22.4125	84.88333333	A		Stone	Regular	Gatitanger Mines	DEPOSIT	
Odissa	22.20388889	84.4925	A	TATA Steel Ltd.	Stone	Regular	Dolomite Quarry	DEPOSIT	
Odissa	22.36583333	84.91777778	A	G.C. Rout	Stone	Regular	Banrai Mine	DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Odissa	21.87472916	87.25095367	A			Regular		DEPOSIT	
Odissa	21.85471153	87.23200226	A			Regular		DEPOSIT	
Odissa	21.81580734	87.21580505	A			Regular		DEPOSIT	
Odissa	21.79028893	87.17662811	A			Regular		DEPOSIT	
Odissa	21.75778198	87.19836426	A			Regular		DEPOSIT	
Odissa	21.73169708	87.20738983	A			Regular		DEPOSIT	
Odissa	21.710186	87.22249603	A			Regular		DEPOSIT	
Odissa	21.65589905	83.52071381	A			Regular		DEPOSIT	
Odissa	21.51998711	83.88197327	A			Regular		DEPOSIT	
Odissa	21.28512192	83.91784668	A			Regular		DEPOSIT	
Odissa	21.40004539	86.03668976	A			Regular		DEPOSIT	
Odissa	21.32278061	86.0794754	A			Regular		DEPOSIT	
Odissa	21.14566612	86.19400024	A			Regular		DEPOSIT	
Odissa	21.04073334	86.25788879	A			Regular		DEPOSIT	
Odissa	21.01927948	85.23577881	A			Regular		DEPOSIT	
Odissa	20.84151649	84.11108398	A			Regular		DEPOSIT	
Odissa	20.89032364	84.23322296	A			Regular		DEPOSIT	
Odissa	20.82151985	85.69102478	A			Regular		DEPOSIT	
Odissa	20.8498745	85.30319214	A			Regular		DEPOSIT	
Odissa	20.86719513	84.29351807	A			Regular		DEPOSIT	
Odissa	20.86865425	84.18010712	A			Regular		DEPOSIT	
Odissa	20.76719475	84.37792206	A			Regular		DEPOSIT	
Odissa	20.84335136	84.14086151	A			Regular		DEPOSIT	
Odissa	20.80741501	84.33992767	A			Regular		DEPOSIT	
Odissa	20.70331955	84.51875305	A			Regular		DEPOSIT	
Odissa	20.66493988	84.59130096	A			Regular		DEPOSIT	
Odissa	20.49583817	84.93925476	A			Regular		DEPOSIT	
Odissa	20.4973259	85.8316803	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Odissa	20.4625721	85.83934021	A			Regular		DEPOSIT	
Odissa	20.49032402	84.9099884	A			Regular		DEPOSIT	
Odissa	20.49052238	85.87957764	A			Regular		DEPOSIT	
Odissa	20.4664402	85.95043182	A			Regular		DEPOSIT	
Odissa	20.46099472	84.99000549	A			Regular		DEPOSIT	
Odissa	20.45674896	85.02820587	A			Regular		DEPOSIT	
Odissa	20.44687462	85.01494598	A			Regular		DEPOSIT	
Odissa	20.44617271	85.72633362	A			Regular		DEPOSIT	
Odissa	20.44341278	85.62723541	A			Regular		DEPOSIT	
Odissa	20.44596672	85.66049957	A			Regular		DEPOSIT	
Odissa	20.43327141	85.92649841	A			Regular		DEPOSIT	
Odissa	20.42875862	85.74205017	A			Regular		DEPOSIT	
Odissa	20.43268967	86.06639862	A			Regular		DEPOSIT	
Odissa	20.34474945	86.26300812	A			Regular		DEPOSIT	
Odissa	20.42092133	85.62139893	A			Regular		DEPOSIT	
Odissa	20.42082405	85.06687927	A			Regular		DEPOSIT	
Odissa	20.41719818	85.1164093	A			Regular		DEPOSIT	
Odissa	20.40890503	85.98030853	A			Regular		DEPOSIT	
Odissa	20.3944664	85.97574615	A			Regular		DEPOSIT	
Odissa	20.39758492	85.52820587	A			Regular		DEPOSIT	
Odissa	20.40111542	85.56793976	A			Regular		DEPOSIT	
Odissa	20.39003754	85.13217163	A			Regular		DEPOSIT	
Odissa	20.38231277	85.87656403	A			Regular		DEPOSIT	
Odissa	20.39018059	85.43619537	A			Regular		DEPOSIT	
Odissa	20.38425636	85.1772995	A			Regular		DEPOSIT	
Odissa	20.37966728	85.94622803	A			Regular		DEPOSIT	
Odissa	20.36904526	85.22966003	A			Regular		DEPOSIT	
Odissa	20.36880684	85.43041992	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Odissa	20.36624908	85.32626343	A			Regular		DEPOSIT	
Odissa	20.37261009	85.96391296	A			Regular		DEPOSIT	
Odissa	20.36479568	85.8866272	A			Regular		DEPOSIT	
Odissa	20.35907173	86.00067902	A			Regular		DEPOSIT	
Odissa	20.33336258	85.87788391	A			Regular		DEPOSIT	
Odissa	20.34130287	86.04055786	A			Regular		DEPOSIT	
Odissa	20.34431458	85.31190491	A			Regular		DEPOSIT	
Odissa	20.31125641	86.06974792	A			Regular		DEPOSIT	
Odissa	20.25110054	85.89137268	A			Regular		DEPOSIT	
Odissa	20.22197533	86.565979	A			Regular		DEPOSIT	
Odissa	20.16417885	86.52256775	A			Regular		DEPOSIT	
Odissa	19.86393166	86.04567719	A			Regular		DEPOSIT	
Odissa	19.78318405	85.78121948	A			Regular		DEPOSIT	
Odissa	19.53138924	84.74442291	A			Regular		DEPOSIT	
Odissa	19.49042511	85.20831299	A			Regular		DEPOSIT	
Odissa	19.49081421	84.91749573	A			Regular		DEPOSIT	
Odissa	19.48673058	84.8342514	A			Regular		DEPOSIT	
Odissa	19.48293114	84.9577179	A			Regular		DEPOSIT	
Odissa	19.41466331	85.02576447	A			Regular		DEPOSIT	
Odissa	20.98819542	86.89100647	A			Regular		DEPOSIT	
Odissa	18.73638889	82.90083333	A			Regular	Granite Mine	DEPOSIT	
Odissa	19.38805556	84.72833333	A		Stone	Regular	Stone Quarry	DEPOSIT	
Odissa	19.38055556	84.73055556	A		Stone	Regular	Stone Quarry	DEPOSIT	
Odissa	19.3075	84.59694444	A		Stone	Regular	Granite Mine	DEPOSIT	
Odissa	20.78322983	86.96466064	A			Regular	Unconsolidated Material	DEPOSIT	
Odissa	21.8975	86.6675	A		Stone	Regular	Gundihudi Stone Quarry	DEPOSIT	
West Bengal	24.073604	87.60262	A		Stone	Regular	Pachami Stone Quarry	DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
West Bengal	23.79148293	87.1131134	A			Regular		DEPOSIT	
West Bengal	23.72818565	87.29746246	A			Regular		DEPOSIT	
West Bengal	23.69482803	87.41105652	A			Regular		DEPOSIT	
West Bengal	23.58288574	87.11387634	A			Regular		DEPOSIT	
West Bengal	23.4174118	87.3971405	A			Regular		DEPOSIT	
West Bengal	23.20194244	87.90195465	A			Regular		DEPOSIT	
West Bengal	22.28513908	88.08239746	A			Regular		DEPOSIT	
West Bengal	22.23189735	88.01669312	A			Regular		DEPOSIT	
West Bengal	22.21331787	86.80273438	A			Regular		DEPOSIT	
West Bengal	22.22153473	86.90776825	A			Regular		DEPOSIT	
West Bengal	22.21629524	86.98841858	A			Regular		DEPOSIT	
West Bengal	22.09030342	87.15032959	A			Regular		DEPOSIT	
West Bengal	21.93014526	87.25741577	A			Regular		DEPOSIT	
West Bengal	21.64152336	87.55584717	A			Regular		DEPOSIT	
West Bengal	22.16844368	88.16222382	A			Regular		DEPOSIT	
West Bengal	22.1517849	88.17700958	A			Regular		DEPOSIT	
West Bengal	22.00333786	88.11071777	A			Regular		DEPOSIT	
West Bengal	21.63806534	88.14254761	A			Regular		DEPOSIT	
West Bengal	23.19027778	87.91833333	A		Sand	Regular	Sand Unit	DEPOSIT	
West Bengal	23.19277778	87.91194444	A		Sand	Regular	Sand Unit	DEPOSIT	

Table A22. Materials database – Myanmar – aggregate (ERDC-CERL).

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Ayeyarwaddy	18.00916862	95.45452881	A			Regular		DEPOSIT	
Ayeyarwaddy	17.43327713	95.66410828	A			Regular		DEPOSIT	
Ayeyarwaddy	17.39693451	95.66200256	A			Regular		DEPOSIT	
Ayeyarwaddy	17.37334061	95.62211609	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Ayeyarwaddy	17.11427498	95.65829468	A			Regular		DEPOSIT	
Ayeyarwaddy	16.99448013	95.53495026	A			Regular		DEPOSIT	
Ayeyarwaddy	15.99781227	95.68989563	A			Regular		DEPOSIT	
Bago	18.90195274	95.15530396	A			Regular		DEPOSIT	
Bago	18.75514412	95.20927429	A			Regular		DEPOSIT	
Bago	18.59964371	95.08102417	A			Regular		DEPOSIT	
Bago	18.55829239	95.10248566	A			Regular		DEPOSIT	
Bago	18.52223969	95.09140778	A			Regular		DEPOSIT	
Bago	18.47839737	95.15291595	A			Regular		DEPOSIT	
Bago	18.46626472	95.18160248	A			Regular		DEPOSIT	
Bago	18.36207962	95.25691223	A			Regular		DEPOSIT	
Bago	18.3429985	95.28852081	A			Regular		DEPOSIT	
Bago	18.33791161	95.32313538	A			Regular		DEPOSIT	
Bago	18.27142525	95.36268616	A			Regular		DEPOSIT	
Bago	18.24669075	95.37270355	A			Regular		DEPOSIT	
Bago	18.17687988	95.40369415	A			Regular		DEPOSIT	
Bago	18.08500481	95.44252014	A			Regular		DEPOSIT	
Kayin	17.26614952	97.6556015	A			Regular		DEPOSIT	
Kayin	16.94269753	97.6421814	A			Regular		DEPOSIT	
Magway	21.57343292	95.27497101	A			Regular		DEPOSIT	
Magway	21.22597313	94.87916565	A			Regular		DEPOSIT	
Magway	21.218153	94.85914612	A			Regular		DEPOSIT	
Magway	21.21360588	94.83263397	A			Regular		DEPOSIT	
Magway	21.0914669	94.80820465	A			Regular		DEPOSIT	
Magway	20.90031433	94.80030823	A			Regular		DEPOSIT	
Magway	20.87473106	94.77803802	A			Regular		DEPOSIT	
Magway	20.67975807	94.7339859	A			Regular		DEPOSIT	
Magway	20.65143585	94.76409912	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Magway	20.58400345	94.79763794	A			Regular		DEPOSIT	
Magway	20.57150459	94.79499054	A			Regular		DEPOSIT	
Magway	20.51782989	94.81263733	A			Regular		DEPOSIT	
Magway	20.5255146	94.83318329	A			Regular		DEPOSIT	
Magway	20.50543785	94.84014893	A			Regular		DEPOSIT	
Magway	20.49777985	94.78507996	A			Regular		DEPOSIT	
Magway	20.46948433	94.84454346	A			Regular		DEPOSIT	
Magway	20.35735512	92.74880219	A			Regular		DEPOSIT	
Magway	20.32662773	94.90891266	A			Regular		DEPOSIT	
Magway	20.25123405	94.91674042	A			Regular		DEPOSIT	
Magway	20.24375534	94.88456726	A			Regular		DEPOSIT	
Magway	20.18326187	94.9105072	A			Regular		DEPOSIT	
Magway	20.16381073	94.90606689	A			Regular		DEPOSIT	
Magway	20.13332748	94.90868378	A			Regular		DEPOSIT	
Magway	20.10307121	94.92698669	A			Regular		DEPOSIT	
Magway	20.04171181	94.99369812	A			Regular		DEPOSIT	
Magway	20.03225327	95.01050568	A			Regular		DEPOSIT	
Magway	20.00342369	95.00064087	A			Regular		DEPOSIT	
Magway	19.99802017	94.99920654	A			Regular		DEPOSIT	
Magway	19.99961281	95.00035095	A			Regular		DEPOSIT	
Magway	19.74621963	95.15290833	A			Regular		DEPOSIT	
Magway	19.64279747	95.1807251	A			Regular		DEPOSIT	
Magway	19.60296631	95.17811584	A			Regular		DEPOSIT	
Magway	19.55036736	95.1802597	A			Regular		DEPOSIT	
Magway	19.4455204	95.18750763	A			Regular		DEPOSIT	
Magway	19.18740463	95.18226624	A			Regular		DEPOSIT	
Magway	19.08206367	95.13349915	A			Regular		DEPOSIT	
Mandalay	21.31295395	95.13739777	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Mandalay	21.23757744	94.979599	A			Regular		DEPOSIT	
Mandalay	21.13588905	94.84803009	A			Regular		DEPOSIT	
Mandalay	21.0502739	94.83370209	A			Regular		DEPOSIT	
Mandalay	21.0273304	94.85174561	A			Regular		DEPOSIT	
Mandalay	20.96690941	94.8520813	A			Regular		DEPOSIT	
Mon	15.90446186	97.68051147	A			Regular		DEPOSIT	
Mon	15.19157314	97.79306793	A			Regular		DEPOSIT	
Sagaing	23.05962563	94.42971802	A			Regular		DEPOSIT	
Sagaing	22.97296333	94.68512726	A			Regular		DEPOSIT	
Sagaing	22.92260742	94.73967743	A			Regular		DEPOSIT	
Sagaing	22.92710114	94.47332764	A			Regular		DEPOSIT	
Sagaing	22.89162636	94.74744415	A			Regular		DEPOSIT	
Sagaing	22.88932037	94.51520538	A			Regular		DEPOSIT	
Sagaing	22.8705883	94.74525452	A			Regular		DEPOSIT	
Sagaing	22.82986259	94.7072525	A			Regular		DEPOSIT	
Sagaing	22.74799538	94.70970917	A			Regular		DEPOSIT	
Sagaing	22.72416687	94.73527527	A			Regular		DEPOSIT	
Sagaing	22.69141769	94.76956177	A			Regular		DEPOSIT	
Sagaing	22.6279068	94.76622009	A			Regular		DEPOSIT	
Sagaing	22.58049011	94.76541138	A			Regular		DEPOSIT	
Sagaing	22.53051186	94.80664063	A			Regular		DEPOSIT	
Sagaing	22.42002296	94.8913269	A			Regular		DEPOSIT	
Sagaing	22.38816643	94.97015381	A			Regular		DEPOSIT	
Tanintharyi	12.3548708	98.63831329	A			Regular		DEPOSIT	
Tanintharyi	12.34427643	98.66067505	A			Regular		DEPOSIT	
Tanintharyi	12.13108063	98.62129211	A			Regular		DEPOSIT	
Tanintharyi	11.80351639	98.80362701	A			Regular		DEPOSIT	
Tanintharyi	11.76657581	98.79493713	A			Regular		DEPOSIT	

City	Latitude	Longitude	Precision	Company	Product	Industry Type	Site Name	Site Type	Capacity (mil. MT reserve)
Tanintharyi	11.72845364	98.83769989	A			Regular		DEPOSIT	
Tanintharyi	11.06563187	98.70842743	A			Regular		DEPOSIT	
Tanintharyi	11.04813004	98.71707916	A			Regular		DEPOSIT	
Tanintharyi	10.41188717	98.50727081	A			Regular		DEPOSIT	
Tanintharyi	10.16766739	98.51376343	A			Regular		DEPOSIT	
Tanintharyi	13.71219254	98.25854492	A			Regular		DEPOSIT	
Tanintharyi	12.78095913	98.63514709	A			Regular		DEPOSIT	
Tanintharyi	12.68827438	98.6675415	A			Regular		DEPOSIT	
Tanintharyi	12.65987206	98.65148926	A			Regular		DEPOSIT	
Tanintharyi	12.57059669	98.65151978	A			Regular		DEPOSIT	
Tanintharyi	12.57074833	98.62865448	A			Regular		DEPOSIT	
Tanintharyi	12.55394459	98.4076767	A			Regular		DEPOSIT	
Tanintharyi	12.51451397	98.50247955	A			Regular		DEPOSIT	
Tanintharyi	12.5036869	98.51123047	A			Regular		DEPOSIT	
Tanintharyi	12.37440872	98.54085541	A			Regular		DEPOSIT	
Tanintharyi	12.1672802	98.6427536	A			Regular		DEPOSIT	
Tanintharyi	12.11558819	98.62853241	A			Regular		DEPOSIT	
Tanintharyi	11.77754593	98.77378082	A			Regular		DEPOSIT	
Tanintharyi	11.03215408	98.71684265	A			Regular		DEPOSIT	
Tanintharyi	10.96097946	98.51573181	A			Regular		DEPOSIT	
Tanintharyi	10.88639545	98.50855255	A			Regular		DEPOSIT	
Tanintharyi	10.85498238	98.62689209	A			Regular		DEPOSIT	
Tanintharyi	10.53902817	98.49855041	A			Regular		DEPOSIT	
Tanintharyi	10.50745296	98.48674774	A			Regular		DEPOSIT	
Tanintharyi	10.45160294	98.49282074	A			Regular		DEPOSIT	
Tanintharyi	10.34353161	98.53365326	A			Regular		DEPOSIT	

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14. ABSTRACT

To sustain itself as the world's premier land power, the Army needs the capability to support expeditionary forces by projecting a minimal basing footprint with reduced logistical burdens. Strategically sited Contingency Bases (CBs) allow the Army's expeditionary forces to rapidly respond and attack the enemy throughout the joint area of operations (JOA). Strategic conditions will be analyzed through the lens of eight OE variables—political, military, economic, social, information, infrastructure, physical environment, and time (PMESII-PT). The Army has neither a well-grounded methodology nor the tools that enable this strategic decision-making capability. Decision makers require reliable information about the situational dynamics of the operational environment to anticipate the impacts that siting and operating CBs will have on the local context, and to consider the effects of the sites on the operation of CBs. This capability to anticipate CB impacts and resources draws upon knowledge gleaned from the local population and becomes particularly important for engagement operations when CBs will have a longer duration of use and interaction with the local populace. This report considers access of building materials required for the construction of CBs and develops a methodology for strategically siting CBs that can be replicated in other locations throughout the world. This work then validates the developed methodology with a case study of Dhaka, Bangladesh.

15. SUBJECT TERMS
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